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AN ANALYSIS OF THE PERFORMANCE-RISK
TRADE-OFF IN SOURCE SELECTION
DECISION MAKING

THESIS

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AFIT/GSM/LAS/93S-18

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DECISION MAKING

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Presented to the Faculty of the Graduate School
of Logistics and Acquisition Management
of the Air Force Institute of Technology
Air University

In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Systems Management

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September 1993

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Acknowledgements

This research effort would not have been possible without the assistance and support of many people. First, we would like to thank our advisors, Lt Col Carl Templin and Maj Kevin Grant. Their ideas, guidance, direction and enthusiasm helped immensely in undertaking this effort.

Next, we would like to thank our sponsor, the RFP and Source Selection Support Program Office, ASC, WPAFB. We want to specifically thank Col Jack Gotcher, Jim Witham, and Dan Southam. Their guidance on policy and "real-world" applications was invaluable in developing and administering the survey.

Finally, we want to thank our families for their support during our military and AFIT experiences. You provided much welcomed distractions at the proper moments.

Rick Pierce
Jeff Wainwright

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Abstract

Each year the Air Force awards weapon system contracts worth billions of dollars using the source selection process. In the source selection, performance and risk assessments are evaluated to determine the best proposal; the proposal that gives the best overall value.

The purpose of this research was to investigate the performance/risk trade-off in the source selection decision making process. The study also examined the effect individual risk propensities and the nature of item being evaluated have on the performance/risk trade-off decisions.

Air Force acquisition personnel stationed at Aeronautical Systems Center, Wright-Patterson AFB, OH, who had participated in a source selection were surveyed. Respondents were asked to rank the color-risk combinations used in a source selection from most to least preferred. Respondents indicated their degree of preference between color-risk rating pairs. Comparisons were made for two item summary levels: technical capability and management.

A definite rank order exists among color-risk ratings. The rank is as follows: Blue-Low, Green-Low/Blue-Moderate (tied), Green-Moderate, Blue-High, Yellow-Low, Green-High, Yellow-Moderate, and Yellow-High. Risk propensity and item summary level do not significantly influence the rank order.

AN ANALYSIS OF THE PERFORMANCE-RISK TRADE-OFF IN SOURCE SELECTION DECISION MAKING

I. Introduction

General Issue

Each year the Air Force (AF) awards many weapon system contracts worth billions of dollars. At completion, some of these contracts exceed budget and schedule performance requirements established at contract award. These overruns are of great concern to AF programming and planning personnel, especially at the higher echelons. In today's acquisition environment where budgets are tight, scrutiny comes from many sources, both internal and external to the program. The primary concern is that capable and cost effective weapon systems are purchased within baselined standards.

Source selection is the process the AF uses to competitively award weapon system contracts. The regulations covering the source selection process state the principal objective is:

to select the offeror whose proposal has the highest degree of credibility, and whose performance can best meet the government's requirements at an affordable cost...The process must be efficient and capable of balancing

technical, cost, and business considerations consistent with requirements... (5:3).

These subjectively evaluated standards are intended to provide a framework for arriving at award decisions without constraining any options available to the source selection team. There are no mandates to award a contract based on lowest bid, shortest schedule, highest performance, or lowest risk. These elements are weighed along with business considerations to determine the most advantageous approach to meet the government's needs.

Of all the elements stated above, risk is the area that presents the greatest management challenge to the source selection team. The regulations give the source selection team the most flexibility in dealing with risk. The regulations require the source selection team to establish a strategy to minimize risk, but the regulations do not define risk. The definition of risk is left to the individuals involved in the source selection. These individuals make decisions concerning risk based upon their preferences and experiences (15:22). The results of source selection decisions can vary due to individual perceptions of risk. Therefore, understanding one's perspective on risk is critical when evaluating the reasons for a specific decision.

In order to determine the role of risk in management decisions, MacCrimmon and Wehrung assert that "the first priority should be to study people whose profession it is to make risky decisions. Prime candidates then, are managers at the top levels of business firms" (15:53). In the AF, these managers are acquisition professionals participating in the source selection process.

Problem Statement

In 1969, Deputy Secretary of Defense David Packard wrote a memorandum to the services listing inadequate risk assessment as a major problem area in system acquisition (3:2-1). In 1981, Deputy Secretary of Defense Frank C. Carlucci, III, published a memorandum aimed at improving the acquisition process. It required the Department of Defense action to increase the visibility of technical risk of weapon systems acquisition programs (3:2-1). Risk assessment and management are important elements in system acquisitions to Department of Defense leadership.

In the source selection environment, cost, schedule and technical performance risk are evaluated and traded-off to arrive at an award decision (5:3). "While cost and schedule are understood, the impact of cost/schedule decisions as they relate to technical performance risk are usually not as clear" (3:2-2,2-3). Since the effects of technical

performance risk are not well understood, this area needs further study.

The problem being addressed by this study is the effects of performance/risk trade-off decisions in the source selection environment.

Research Objective

The purpose of this research is to determine whether participants in the source selection process are consistent in their performance/risk trade-off decisions or whether there are differences based on individual risk propensity. It also assesses whether such trade-offs vary by the nature of the item being evaluated.

Investigative Questions

To meet the objective of our research question, the following five investigative questions need to be answered:

1. What is the risk propensity of the source selection participants?
2. How do source selection participants trade-off performance versus risk?
3. Does risk propensity influence the trade-off decision?
4. Does the performance versus risk trade-off decision vary based on the item being evaluated?

5. To what degree are color-risk ratings preferred over one another?

Assumptions and Limitations

Several assumptions were made which limit the scope of this investigation and the applicability of this research.

The first assumption is that the response of individuals surveyed accurately reflects how they would decide when participating in an actual source selection. The questions provided in our survey are hypothetical. As such, the survey respondents are presented with imaginary scenarios. MacCrimmon and Wehrung report that when asked to respond in this manner, people tend to view risk as less threatening (15:121). This tendency can cause individuals to appear more risk prone than they actually are.

The next assumption is that survey respondents will answer the survey with respect to their professional propensity for dealing with risk. MacCrimmon and Wehrung found that individuals treat the trade-off of money versus risk differently in their personal and professional lives (15:176). This research attempts to minimize this effect by distributing the survey in the work place and asking participants to make trade-off decisions in a government source selection context.

The final assumption is that individuals who have participated in source selections are not biased by whether the source selection was formal or streamlined.

One limitation of this research effort stems from differences in individual perceptions concerning relative amounts of money. Variances in individual responses can occur because of the different sizes of programs. Incremental changes in amounts of money are viewed with relativity (24:454). "A \$1,000 change of costs from \$1,000 to \$2,000 is typically more significant than from \$60,000 to \$61,000. The choice of dollar figures could influence risk assessment" (22:12). Another example of this is that the relative value of \$100,000 to a person who typically deals with a million dollar contracts is different from one who deals with billion dollar contracts.

There are limitations associated with the research sample. The sample was taken from people who have participated in source selections at Wright-Patterson Air Force Base (WPAFB) Aeronautical Systems Center (ASC) and are still assigned there. This sample population will not be a perfect indicator of future source selection behavior as it does not contain anyone who will participate on a ASC source selection team for the first time. A typical source selection team consists of a core of experienced people (those who have participated in prior source selection) and some people who are participating for the first time.

The research is further limited by the fact that it cannot completely address all the trade-offs involved in the final award decision. The best indicator of how source

selection decisions are made resides with the Source Selection Authority (SSA), as the SSA makes the final award decision. The population of SSAs is very small at ASC as the dollar thresholds of the weapon systems being acquired typically require the source selection authorities to be at least the Commander of ASC. Since only two or three SSAs would be available for study, no significant statistical conclusions could be drawn from data collected on SSAs. Although the research does not profile the actual decision maker, it does measure the decisions of those who have the potential to influence SSAs the most. The source selection evaluators also possess the potential to become SSAs.

Overview of the Thesis Structure

This chapter has presented the general issue, problem statement, research objectives, investigative questions, and assumptions and limitations of this research effort.

Chapter II examines general risk concepts, risk related behavior, and source selection risk management guidance in the Department of Defense (DoD). Based on the current literature, it supports the research of source selection team members' risk propensity based on the use of a source selection evaluation matrix.

Chapter III discusses the methodology used to guide the research effort toward answering the investigative questions

put forth earlier in this chapter. Chapter III also discusses the method of data collection and the methods of analysis.

Chapter IV presents the results of the study. Statistical tests and levels of significance are used to relate findings back to the investigative questions posed.

Finally, chapter V contains conclusions and suggestions for areas of further research.

II. Literature Review

Introduction

Nowhere is risk information being used more in the Department of Defense (DoD) than in systems acquisition (22:36-37). MacCrimmon and Wehrung assert in their book

Taking Risks that:

the first priority [when studying risk] should be to study people whose profession it is to make risky decisions. Prime candidates then, are managers at the top levels of business firms (15:53).

Therefore, in order to effectively study risk management in DoD systems acquisition, these decision makers need to be studied. This literature review examines general risk concepts, risk related behavior, and DoD's source selection risk management guidance. The review supports the study of the performance/risk trade-off in source selection decision making.

The literature review begins with an examination of various definitions of risk culminating in the establishment of a working definition for this review. The ideas of the presence of risk, the need for risk and people's behavior when confronting risk are developed. Next, the various methods of studying individual risk propensity are discussed. This examination provides the framework in which to investigate DoD and Air Force (AF) risk management

policies as they relate to general management practices and the source selection process, respectively. Previous research on risk in the source selection process will be examined. The examination of previous research will culminate in a statement of this research topic's significance.

Risk

In order to effectively research risk, a clear definition of risk must be given. The following five definitions are representative of the many sources consulted:

1. Exposure to the chance of injury or loss (19:1139).
2. First, it is necessary that there be a potential loss of some amount. Second, there must be a chance of loss. A sure loss is not a risk. Third, the notion "to expose" means that the decision maker can take actions that can increase the magnitude or chance of loss (15:9).
3. The probability of an undesirable event occurring and the significance of the consequence of the occurrence (3:3-1).
4. A totally inclusive definition of risk includes, dangers, potential for loss, the degree or probability of a specific exposure for loss as well as the liability to injury, damage, loss, or pain. It encompasses jeopardy or the exposure to extreme danger for any situation. Events with both chance and

voluntary provocation are included. Loss potential due to risk also embraces rational behavior, irrational behavior, natural phenomena, and any other potential for realizing unwanted, negative consequences of any event (9:24).

5. The condition of having outcomes with known probabilities of occurrence, not certainty of occurrence (2:B-5).

A common element in each of these definitions is the potential for some type of loss. This raises another question that must be answered; what is a loss? Definitions of loss include:

1. The state of being deprived of or of being without something that one has had (19:792).
2. An outcome that will make us worse off than some reference status quo position (15:10).
3. An outcome that is not as good as some other outcome that might have been obtained (15:10).

The concept of loss helps establish a good working definition for the purpose of this study: risk involves some type of loss (undesirable event) coupled with some type of chance. Now that a definition of risk has been established, investigation of risk itself can begin.

Why Do We Have Risks?

Risks are present in every daily activity. Risk arises in some form in virtually all fields of endeavor. It is

important neither to ignore risk, nor to be frightened by it (17:ix). This is why it is so important to develop an effective way to deal with risk. If managers can be certain of nothing else, they can be certain that they will be faced with choices, that in some degree, involve risk.

Life requires choices; choices require risks. While you can choose to minimize the risks you face, you cannot avoid risks completely. Along with death and taxes, risk is one of the certainties of life (15:4).

"Our choices do not just affect us, they affect many other people. Business and government decisions can influence the risks faced by thousands or millions of others" (15:3). Managers, executives, and all kinds of leaders make decisions involving risks. The decisions they make not only affect their own lives and futures, but also the lives of others to whom their decisions are linked.

Knowing that choices involving risks are always present and have tremendous consequences brings forth two questions:

1. Why do decision makers take risks?
2. What motivates, drives, and possesses decision makers to make risky decisions, knowing that their choice can impact so many others?

In regard to these questions, March and Shapira's research concludes:

1. Risk is essential to success in decision making.
2. Risk taking is an essential component of the managerial role.

3. Managers recognize emotional pleasures and pains of risk taking, the affective delights and thrills of danger. Risk taking involves emotions of anxiety, fear, stimulation, and joy (16:1409).

The risks that decision makers encounter come from a variety of sources. MacCrimmon and Wehrung state, as a result of their research, that there are three basic identifiable determinants of risk: lack of control, lack of information, and lack of time. Risk does not exist if the decision maker has complete control over the situation and can determine the optimal outcome. Also, if the decision maker has perfect knowledge of the situation, risk is eliminated because the decision maker can choose the best alternative. Finally, if the decision maker is not limited by time, the choice can be delayed until the risk is eliminated (15:14-15).

MacCrimmon and Wehrung also describe three components of risk: magnitude of potential loss, chances of potential loss, and exposure to potential loss. To reduce risk in a situation, one of these three components must be reduced. If the decision maker can reduce all three of the components, the situation might not involve any risk at all (15:10). The outcome of risk is directly related to the three determinants and three components of risk. Table 1 illustrates the impact on the decision maker under the various combinations of determinants and components of risk.

All of the risk determinants and components need to be addressed by not only managers and executives, but by everyone in day-to-day activities. The way a manager deals

Table 1

Relationships Between Components (columns) and
Determinants of Risk (rows) (15:19)

	Magnitude of Potential Loss	Chances of Potential Loss	Exposure to Potential Loss
Lack of Control	Cannot affect size of potential loss	Cannot affect chances of potential loss	Cannot affect exposure to potential loss
Lack of Information	Do not know size of potential loss	Do not know chances of potential loss	Do not know exposure to potential loss
Lack of Time	Insufficient time to understand or reduce magnitude of potential loss	Insufficient time to understand or reduce chances of potential loss	Insufficient time to understand or reduce exposure to potential loss

with these determinants and components of risk varies from individual to individual. These variances lead to an area of risk that must be analyzed; individual behavior of those who confront, handle, and make choices concerning risk.

Risk Behavior

Everyone, regardless of their position, goes through a process to manage the determinants and components of risk. How a manager chooses to accomplish this process, is directly related to the manager's risk propensity. The process varies from individual to individual, but the process takes a common form; some type of choice involved, where one of the choices includes a chance of a loss.

This focus on choice captures the core of a risky situation - but only the core. At some point a person will make a choice, but a lot of things can happen before the choice is made. Knowing these things can often tell us more about risk behavior than the choice itself (15:20-21).

Before managers can choose among alternative options, they must first recognize that a risky situation exists.

A person acquires some information about a situation that may result in his losing something of value. Although an omniscient outside observer may be able to make an "objective" appraisal of the risks, the decision maker himself may perceive the situation in a very different way (15:21-22).

The decision maker's choice is dependent upon how he perceives the risks involved with his alternatives. These same perceptions then become part of the second step, evaluating the risks in a particular situation.

The individual overtly acts to expose himself to some risky situations; others he overtly acts to avoid, while others he accepts as they confront him. In each case the individual evaluates the acceptability of the risks (15:23-24).

After the decision maker recognizes and evaluates the risk in a particular situation, adjustments can be made. How or even if the decision maker decides to adjust a risk, depends upon how active or passive the decision maker is. Individuals that display active behavior will try to adjust the risks, while those who display passive behavior will simply choose among the existing alternatives (15:24-25).

If a decision maker decides that the risks need to be adjusted, there are three basic ways to adjust the risks. The decision maker can try to gain more control over the situation, more information about the situation, or more time to deal with the situation (15:28).

After all of this has been accomplished, the decision maker arrives at the crux of managing risk: choosing among the alternatives. The decision maker must select an alternative based on what cannot be adjusted. This choice is directly related to the risk propensity of the decision maker (15:25).

When it comes to risk propensity, people can be categorized into one of three categories: risk averter, risk neutral, and risk taker (15:34). Risk averters, risk neutrals, and risk takers act differently when managing risks.

A risk taker would accept a higher exposure in the sense of taking sole responsibility, acting with less information, and requiring less control than would a risk averter. The risk taker would accept

a higher chance of loss, would operate in unfamiliar situations, would tolerate more uncertainty, and would require less information about the chances [than would a risk averter] (15:34).

Risk neutrals would fall somewhere between risk takers and risk averters; their actions displaying some tendencies of both characteristics (15:93).

The categorization of an individual's risk propensity is partially dependent upon several uncontrollable factors. The following researchers have studied some of these factors. Hudgens and Fatkin found that men were observed to be more likely to make decisions involving greater risks than women (12:204). Hayden and Thomas found that military rank, line/staff designation and sex influence risk propensity (11:64-76). For example, male, high ranking, line officers were more risk seeking than lower ranking, female, staff officers. Hamilton's research demonstrated Atkinson's theory: people who have high need for success tend to be more risk seeking than those who have a high need to avoid failure (10).

MacCrimmon and Wehrung conducted a comprehensive study of these uncontrollable factors on over 500 top level American and Canadian managers (15:xii). They investigated the relationship between risk propensity and personal factors such as age, education, nationality, sex, or

management level. They also studied the relationship between risk propensity and situational factors such as firm size, industry, and whether the decision was business or personal in nature (15:xii). Their findings include:

1. Younger managers take more risks than older managers,
2. Managers with few dependents take more risks than managers with many dependents,
3. Managers with postgraduate education take more risks than managers with a bachelor's degree or less,
4. Managers with more wealth take more risks,
5. Managers with higher incomes take more risks,
6. Higher level managers take more risks than lower level ones,
7. Managers with more authority take more risks,
8. Managers with less seniority take more risks than those with more seniority,
9. Most successful executives take more risks,
10. No evidence was found to link risk propensity and nationality (15:247-267).

Research indicates that risk behavior cannot be predicted solely from utility theory (7; 13; 15; 21). Other personal and situational factors also influence risk behavior. Now that a general framework of risk behavior has been established, the methods for studying risk propensity will be addressed.

Studying Risk

The classic method of studying risk is utility theory.

The case of decision making under risk is one in which considerable consensus exists among decision experts as to how one ought to choose. The theory advises which alternative to select in complex decision situations on the basis of one's basic taste and preferences about risk and the intrinsic value of the attribute(s) under consideration. Both of these elements are captured through a utility function so that maximizing expected utility becomes the guide to rational behavior in more complex situations (21:11).

Applying utility theory should make most decisions relatively easy. The logical choice can be determined through sound, rational, objective reasoning. To illustrate this, Schoemaker presents the rational man. The rational man concept views an ideal person (starting with Greek philosophy) as someone leading a placid life amid external turmoil by applying reason to conduct (21:2). The idea of the rational man consists of three fundamental beliefs:

1. people have preference structures that obey certain axioms of well-behavedness so that
2. a mathematical representation can be rendered of these preference structures and
3. choice can be modelled as maximizing an imputed objective function (e.g., expected utility) subject to certain economic constraints (21:2).

Contrary to this ideal model, it has been shown that decision makers do not make choices based entirely on

utility (15; 17; 21). They are constantly making decisions that violate the principles of the expected utility theory (14:806). Edwards and Von Winterfeldt cite a study that demonstrates this behavior. The subjects of the study were given the task of choosing between two lotteries. The first lottery gave them the opportunity to win a moderate amount of money with a high probability of success. The second lottery gave them the opportunity to win a large amount of money, but with a low probability of success. The subjects were then asked to bid for these lotteries. The rational man, when applying the principles of expected utility, would pay more for the first lottery. Contrary to the expected response, most subjects were willing to pay more for the second lottery, violating sound, rational, objective reasoning (6:664).

Short and long term perspectives are other factors that influence decisions along with expected utility. "Risk affects decision making such that choices which will yield the highest expected utility in the long term are often not made" (22:20). Expected utility does not influence long term and short term choices in the same fashion.

Moore concludes that when a particular choice will produce a success 70% of the time, the 30% chance of failure may be insignificant to someone who will make the choice once, but may be too risky for a decision maker who will make the same choice several times (17:8). The result is a

focus solely on the probabilities of the outcome and not on sound, rational, objective reasoning.

Several studies have been conducted on risk related behavior and decision making. For decisions involving choice, MacCrimmon and Wehrung found five common generalities:

1. The managers showed a very different willingness to take risks across the standardized situation.
2. Managers were more risk averse when their own money was at stake than when their firm's resources were at stake.
3. Risk taking was more common in the recognition and adjustment phases of risk than in the choice phase.
4. Managers were more willing to take risks once in a risky situation than in entering it.
5. A manager's willingness to take risks in one standardized situation was only weakly related to his willingness to take risks in seemingly similar situations. (15:269)

Skibinski conducted a study, applying these ideas to the field of logistics. He surveyed 117 managers and students in the field of logistics. His study concluded that risk, in general, significantly affected decisions. He further concluded that policy addressing risk can influence risk-inherent decisions, but no generalizations can be made about risk policy. Skibinski finally concluded that:

The implication to logistics organizations is that a risk policy which is stated in vague or uncertain terms may not yield the desired results. Management's attempt to influence risk-related decisions may only be successful in specific situations. The policy will likely not be applied to all decision variables uniformly. Even a vague policy, however, will reduce the level of risk taking compared to no policy at all (22:104).

Skibinski's study shows that policy cannot effectively control how the individual decision makers deal with risk. Policies will influence decisions to certain degrees, but no matter how much direction and guidance the decision maker is given, the decision is unique unto him. This is even more apparent in DoD Systems Acquisition.

Risk Management in the DoD

Harold J. Schutt, Associate Dean, Department of Research and Information, Defense Systems Management College (DSMC), states in the preface of Risk Management Concepts and Guidance:

There are no "textbook" answers to risk management. Each situation is different and each circumstance requires a slightly different approach" (3:preface).

As Schutt's statement implies, DoD managers are given latitude in handling risk. Most DoD regulations and policies dealing with risk provide frameworks from which decision makers are allowed to manage risk. These frameworks mostly consist of guidelines, suggestions, and

experiences that are presented to help managers deal with risk. Specific answers are rarely found for most situations.

One risk management approach that is used quite commonly in the DoD environment is to classify risk into its various facets. The five facets are: technical, programmatic, supportability, cost, and schedule (3:3-3). Dividing risk into these five facets helps in "understanding the source of the risk and the impact area(s) as well as providing a structure to examine risk...if the risk is to be managed effectively" (3:3-3). These facets surface in the guidelines set forth in Air Force Regulations (AFR) 70-15, Formal Source Selection for Major Acquisitions, and AFR 70-30, Streamlined Source Selection Procedures, which govern the AF source selection process.

The Air Force Source Selection Process and Risk Assessment

The guidelines for managing risk in the source selection process address the functions which must be assessed, who must make the assessment, and when the assessment must occur. An assessment tool, the source selection evaluation matrix, is also given.

The AF requires an evaluation of risks for all proposals. "The risks which must be assessed are those associated with cost, schedule, and performance or technical

aspects of the program" (4:17; 5:9). These are the same facets recommended in the DSMC risk handbook.

AFR 70-15 and AFR 70-30 state that the risks must be formally assessed by the program office, the offering contractor and the Source Selection Evaluation Board (SSEB) or Source Selection Evaluation Team (SSET). The SSEB and SSET consist of personnel who advise the Source Selection Authority (SSA). The primary difference between these two bodies is that the SSET (a streamlined version of the SSEB) is designed to accelerate the source selection review process (4; 5). For the purpose of this research, the terms SSEB and SSET can be used interchangeably.

The program office will perform its evaluation of risks based upon the request for proposal it releases. The program office is required to submit an independent assessment of risks to the SSEB prior to the receipt of any proposals. The offeror is required to assess risks with the submission of the proposal. The SSEB will make its assessment of risk based upon its review of the offerors' proposal (4; 5).

The guidelines above are the minimum standard for risk assessment during the source selection process. More risk assessment may occur if Air Force managers deem it appropriate.

The source selection evaluation matrix tool is a rating technique that uses color codes (Blue, Green, Yellow, and

Red) to represent the technical performance and the terms High, Moderate and Low to represent the assessed risk of an evaluation area. The definition of the terms are given in Table 2 and Table 3.

The use of these categories results in twelve different possible rankings of a proposal. Figure 1 shows the possible color-risk combinations. The comparison of these ratings in an area will help the SSA make decisions regarding contract award.

Previous Source Selection Risk Related Research

To date, there have been few studies of risk in the DoD source selection environment (18; 20; 23).

Schenning investigated how Air Force managers evaluate risk associated with various program decisions. He concentrated on the major decisions that confront most mid-level Air Force managers, of which source selection was one area (20:8). Schenning's research found that personnel possessing a technical degree were less likely than those without technical degrees to rank technical risk as more important than cost or schedule risk in a source selection environment (20:78). The research illustrates how other factors (such as education) can influence risk behavior in the source selection environment.

Table 2

Definition of Color Rating Codes (4:16; 5:10)

Color Rating	Definition
Blue (Exceptional)	Exceeds specified performance or capability in a beneficial way to the Air Force; and has a high probability of satisfying the requirement; and has no significant weakness.
Green (Acceptable)	Meets evaluation standards; and has good probability of satisfying the requirement; and any weaknesses can be readily corrected.
Yellow (Marginal)	Fails to meet evaluation standards; and has low probability of satisfying the requirement; and has significant deficiencies but correctable.
Red (Unaccept.)	Fails to meet a minimum requirement; and deficiency requires a major revision to the proposal to make it correct.

Table 3

Definition of Risk Assessment Codes (4:16; 5:9)

Risk	Definition
High (H)	Likely to cause significant serious disruption of schedule, increase in cost, or degradation of performance even with special contractor emphasis and close government monitoring.
Moderate (M)	Can potentially cause some disruption of schedule, increase in cost, or degradation of performance. However special contractor emphasis or close government monitoring will probably be able to overcome difficulties.
Low (L)	Has little potential to cause disruption of schedule, increase in cost, or degradation of performance. Normal contractor effort and normal government monitoring will probably be able to overcome difficulties.

	Blue	Green	Yellow	Red
High				
Moderate				
Low				

Figure 1
 Technical Performance/Risk Matrix
 (adapted from 4; 5)

Noffsinger's research looked for the evaluation criteria, used in past AF Logistics Command source selections (base level), that had contributed significantly to the award decision (18:viii). He performed an analysis on historical data finding relationships among award decisions, risk ratings, color ratings and color-risk ratings (18:54-69). Noffsinger found:

Technical risk was more highly correlated with the award decision than the actual color rating, with lower levels of risk being associated with contract award. Combining risk and color ratings yielded even higher correlation (18:79).

Of all the contracts studied, only one winning proposal was not rated low risk (18:56). Noffsinger demonstrated that the offeror evaluation criteria that were most correlated

with the award decision were those that dealt with risk, specifically technical risk. The research does not address the interrelationships among different color-risk ratings. For example, there is no distinction as to whether a Green-High rating is preferable to a Yellow-Low rating.

Thomas examined risk assessment and scoring in the DoD environment in order to develop a scoring model (23). The scoring model was intended to provide a reliable and standardized methodology of deriving area level scores from item and factor level assessments (23:235). The model was constructed using policy guidance and the results of a fact finding questionnaire. The questionnaire asked 69 AF members at Aeronautical Systems Division, who were experienced in source selections, if the present scoring system was adequate. Inputs were solicited from members who stated the present system needed improvements (23:77). The results of Thomas' work resulted in a model that conformed to all the regulations (at that time) and was an improvement over existing scoring models (23:234-238).

The above research examined how risk is evaluated in program decisions, how risk has contributed to the source selection decision and how risk can be modeled to provide consistent proposal scorings in the source selection environment. None of the studies examined how technical color-risk ratings are traded-off by source selection team members.

Summary

This literature review has established a working definition of risk by presenting the common features from the differing viewpoints examined. The results of research studying behavior of managers when confronting risks were identified. Utility theory was used to demonstrate that in many circumstances optimal choices are obtained through sound, rational, objective reasoning. Studies have shown that in spite of utility theory "truths," people do not select the expected choice predicted by utility theory. The affect of risk on these choices in the source selection environment needs to be studied.

DoD and the AF have established policies concerning risk management in the source selection environment. The guidance is intended to assist decision makers in managing the risks involved in the acquisition process. Studies have shown that policies have some influence on the decisions made by managers, but they do not determine the final decision.

None of the previous source selection research studies addresses the risk propensity of source selection decision makers and how their propensity affects their decisions. Previous research efforts focus on historical analysis of source selection decisions. This research provides a better understanding of risk management in the source selection process by examining the risk propensity of the source

selection participants using the color-risk assessment tool
recommended by AFR 70-15 and AFR 70-30.

III. Methodology

Introduction

This chapter explains the methods used to answer the investigative questions posed in Chapter I in support of the research objective. Determination of the population and sample size, development of the survey instrument, reliability and validity issues of the research, and the methods of analyzing the data are discussed. The chapter concludes by addressing how the investigative questions have been addressed.

Population

To accomplish the objective of this research, the study focused on individuals who had participated in a source selection. Specifically, the target population was Air Force (AF) personnel (military and civilian) who have participated in a source selection. The population consisted of acquisition personnel from all Air Force Product and Materiel Centers. The target population is constantly changing as personnel are entering and leaving the acquisition work force through assignment changes, as well as AF accessions and attrition. The population included all officers and civilians who have participated in

at least one source selection and are currently working in the acquisition career field.

Sampling

The sample representing the population of interest was AF acquisition personnel who have participated in a source selection at Wright-Patterson Air Force Base OH (WPAFB), Aeronautical Systems Center (ASC). The sample was further constrained to personnel that were still assigned to WPAFB at the time of survey mailing.

The sample of personnel at ASC is representative of the other product centers. Acquisition personnel generally have experience at more than one product center due to the nature of Department of Defense positions. This is especially true for military personnel. Also, personnel at the product centers have similar educational backgrounds. The personnel also use the same regulations and military standards in conducting business. Therefore, as was shown in the literature review, the aggregate attitudes and perceptions of acquisition personnel at the various product centers should be similar when dealing with risk.

These personnel were identified by the Request For Proposal (RFP) and Source Selection Support Program Office located at WPAFB. This office maintains records on participants in ASC source selections, but information regarding personnel reassignments is not maintained with

this data. To increase the response rate, only participants in recent source selections were surveyed. They identified 202 personnel who met the survey requirements. Due to the dynamic nature of the acquisition work force, the sample represents a moment in time.

Survey Development

A mail survey was selected as the best method to meet the research objective. The survey provided many advantages over observational and experimental methods.

Surveys tend to be more economical than observation and experimentation (8:318). In measuring attitudes and decision processes, observation and experimentation would have required more time than was available to yield an adequate sample size. Observational data is also limited in the fact that attitudes and decision processes are not always visually detectable.

The survey consisted of four sections: I) individual risk propensity, II) source selection evaluation matrix color-risk rankings, III) source selection evaluation color-risk pairwise comparisons, and IV) background information. A copy of the survey is contained in Appendix A.

Section I measured individual risk propensity in terms of choices related to monetary gains and losses. These questions were used to categorize individuals as risk averter, risk neutral and risk taker. The questions were

based on survey questions used by Emmelhainz, Kahneman & Tversky, and Skibinski (7; 13; 22).

The original survey questions presented two choices with different risks and different expected values. For example, individuals were asked if they preferred:

A. An 80% chance of gaining \$4,000 and a 20% chance of gaining \$0, or

B. A certain gain of \$3,000 (22:147).

A risk taker would prefer the first choice while a risk averter would prefer the second choice. There was no risk neutral choice.

In the survey for this research, three different choices were provided. The first two choices involved different probabilities of outcome and monetary values, but had the same expected value. The third choice was for no preference between the first two choices. For example, individuals were asked if they preferred:

A. An 80% chance of gaining \$4,000 and a 20% chance of gaining \$0.

B. A certain gain of \$3,200.

C. No preference.

A risk taker would prefer the first choice because there is a chance of gaining more money with the potential loss of gaining nothing. A risk averter would choose the second choice because there is no risk. A risk neutral would see that the expected values are the same and have no

preference. Table 4 shows the six questions used in the survey and how the responses are associated with risk propensity.

Table 4

Survey Section I:
Risk Propensity Response Categorization

Question	Risk Averter	Risk Neutral	Risk Taker
1	Certain gain of \$3200	No preference	80% chance of \$4000 gain, 20% chance of \$0 gain
2	25% chance of \$3200 gain, 75% chance of \$0 gain	No preference	20% chance of \$4000 gain, 80% chance of \$0 gain
3	Certain loss of \$3200	No preference	80% chance of \$4000 loss, 20% chance of \$0 loss
4	25% chance of \$3200 loss, 75% chance of \$0 loss	No preference	20% chance of \$4000 loss, 80% chance of \$0 loss
5	90% chance of \$3000 gain, 10% chance of \$0 gain	No preference	45% chance of \$6000 gain, 55% chance of \$0 gain
6	90% chance of \$3000 loss, 10% chance of \$0 loss	No preference	45% chance of \$6000 loss, 55% chance of \$0 loss

Section II presented definitions of color and risk ratings used in source selections. The section established

how individuals trade-off performance and risk in their decision processes. Respondents were asked to rank the nine combinations of risk ratings (High, Moderate, Low) and color ratings (Blue, Green, Yellow) from 1 (most preferred) to 9 (least preferred). Figure 2 illustrates a possible ranking from a respondent. The color rating of Red was omitted because any proposal with this rating is not eligible for contract award per AFR 70-15 and AFR 70-30.

Section II also compared rankings between item summary levels. Respondents were asked to complete a matrix for two different item summary levels; technical capability and management.

	Blue	Green	Yellow
High	4	7	9
Moderate	3	5	8
Low	1	2	6

Figure 2

Survey Section II: Example of
Completed Performance/Risk Matrix
(adapted from 4; 5)

Section III provided pairwise comparisons of preferences between selected color-risk combinations from the source selection evaluation matrix. Respondents were asked to indicate their preferences for color-risk pairs using an ordinal scale. Figure 3 illustrates the usage of the ordinal scale in Section III. Selecting a 1 or a 7 indicates the strongest preference for Green-Low or Blue-Moderate respectively. Selecting 4 indicates that there is no preference.

Pairwise comparisons provided another method to establish the rank order structure. It also established the degree of preference between color-risk combinations.

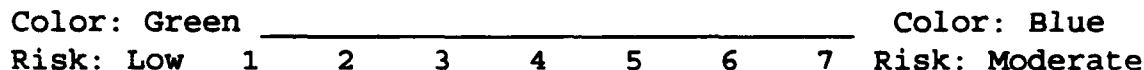


Figure 3

Ordinal Scale Pairwise Comparison of Color-Risk Ratings

Section IV provided background information for the demographics of the sample. The respondents were asked their military rank/civilian grade, years of acquisition experience, acquisition specialty (program management, logistics, program control, etc.) and the highest position held in a source selection. They were also asked to assess their risk propensity in their personal and professional

lives. The demographic questions also provided a means to confirm that survey respondents met the sample's requirements.

Method of Analysis

Risk Propensity Categorization. Individuals were categorized into risk propensity groups based on the results of Section I of the survey. The respondents were given a score of +1 if they chose the riskier option. A score of -1 was given for selecting the less risky option. When no preference was selected, a score of 0 was given. All the scores for the questions were then summed. A negative total indicated that the respondent was a risk averter. A positive total indicated that the respondent was a risk taker. A total of zero indicated that the respondent was risk neutral.

Performance/Risk Trade-Off. Sections II and III were used to answer how source selection participants trade-off performance versus risk. Section II was used to establish rank orders among the various color-risk ratings of the source selection evaluation matrix. Section III was used to establish rank orders by indicating preferences between color-risk rating pairs. The rank orders were established for the entire sample.

Rank orders were established by using the Friedman test (1: 299). The two assumptions of this test are:

1. the b k -variate random variables are mutually independent
2. within each block the observations may be ranked according to some criterion of interest (1: 296 and 299)

By the definition of the source selection evaluation matrix, each of the possible rankings is mutually independent, thus satisfying assumption one. In the test, b is the number of respondents and k is the number of possible ranks of the color-risk ratings (nine). Assumption two is the purpose of Section II, ranking the source selection evaluation matrix combinations.

The null hypothesis for the Friedman test is that "each ranking of the random variables within a block is equally likely" (1:296). The alternate hypothesis is that at least one of the random variables yields larger observed ranks (1:297). Acceptance of the null hypothesis was based on a level of significance (α) equal to 0.05.

In addition to establishing rank order, the Friedman test also establishes the significance between individual rankings so conclusions may be drawn. These decisions could include that rank 1 and rank 2 are statistically different and must fall in that rank order. Another decision could be rank 1, rank 2, and rank 3 are not statistically different

from one another, but all are statistically different from rank 4.

Section III required respondents to indicate preferences according to an ordinal scale. Preference between color-risk rating pairs was identified by examination of the median value. Referring to Figure 3, a median value of 2 indicates that a Green-Low color rating is ranked higher in the overall rank order structure than the Blue-Moderate color rating. The preferences of the color-risk ratings were used to build a rank order. The rank order established by the ordinal scale was compared to the Friedman test rank order results to establish reliability.

Risk Propensity and Trade-Off Decisions. Using the risk propensity categories previously established in the analysis of Section I of the survey, rank order structures were developed for the different risk propensity categories. The rank order structures were developed according to the Friedman test described above. The rank order structures were then compared among risk propensity categories using Spearman rank correlations. Comparisons were also made with the rank order structure of the entire sample.

The Spearman rank correlation coefficient is a statistic that tests for independence between two random variables (1:254). The null hypothesis for the test is that

the random variables are independent. The alternate hypothesis is that the variables are correlated (1:254). The results will indicate differences among rank order structures defined by the risk propensity groups (ie. does risk propensity affect rank order). The Friedman rank sums were used for the Spearman comparisons.

Item Summary and Trade-Off Decisions. Section II required respondents to establish rank orders for two different item summary levels: technical capability and management. Friedman tests were used to establish rank orders by item summary level for the entire sample. The Spearman rank correlation was conducted to compare the rank orders.

Degree of Preference. Section III required respondents to indicate degree of preferences for color-risk rating pairs according to a seven point ordinal scale. Degree of preference between color-risk rating pairs was identified by examination of the median value. A median value of 4 indicated no preference for either color-risk rating. A median value of 1 or 7 indicated a strong preference for one of the color-risk ratings. Median values of 2 and 6 indicated a moderate preference for one of the color-risk ratings, while a 3 or 5 indicated a slight preference for one of the color-risk ratings.

Strategies for Reliability

Reliability focuses on determining the randomness or unstable error of the measurement device (8). To ensure the survey was reliable, the following strategies were used:

1. standardized definitions of color and risk ratings
2. two methods to determine rank order
3. adoption of risk propensity questionnaire used in three previous studies (7; 13; 22)
4. comparison of risk propensity category assignment and respondent self evaluation of risk propensity
5. pretest of survey instrument

The definitions of color and risk ratings used in Sections II and III of the survey were taken directly from the source selection governing regulations, AFR 70-15 and AFR 70-30. Since the target sample had participated in a source selection, these terms (as well as the use of an evaluation matrix) were familiar to the respondents. Random errors due to misrepresentation of actual terminology used in the source selection environment have been eliminated by providing current definitions. The definitions used are valid until the regulations governing the source selection ranking process change.

Reliability was also addressed through the design of the questionnaire. Sections II and III require the respondent to discriminate by preferences among color-risk

ratings. Comparing the results of these sections should reveal similar rank orders. For example, if a Blue-Low risk was ranked second and a Green-High risk was ranked fifth, Section III should also show that in a pairwise comparison the Blue-Low risk was the preferred color-risk rating. Results of constructing the rank order in these two different manners demonstrated internal consistency of the survey. A Spearman rank correlation of 0.9958 was found when comparing the two rank orders.

As previously stated, Section I, risk propensity categorization, was derived from surveys of other risk propensity studies (7; 13; 22). Meta-analysis of these studies found that the results obtained are replicable (22:94-95).

The survey was pretested during the development stage. Pretesting occurred in two steps. The first step was to administer the draft survey to five people who were familiar with survey development. The participants completed the draft survey in the presence of the research team. Participants were encouraged to ask questions and provide criticism of the draft survey. This step was intended to eliminate weaknesses in the measurement technique and ambiguity in the instructions and terminology. The feedback from this step was incorporated into another draft survey for the second step of pretesting.

The second step of pretesting consisted of administering the survey to seven Air Force Institute of Technology students and three personnel in the RFP and Source Selection Support Program Office who met the survey population's requirements and were familiar with survey development. These people were given the survey without any instructions other than to follow the directions of the survey and provide feedback to the research team. This step was intended to test the survey in as realistic environment as possible and to determine the time required to complete the survey. The second pretest step also assured elimination of measurement weaknesses and ambiguities in the instructions and terminology of the survey.

Validity

"Validity is the extent to which differences found with a measuring tool reflect true differences among those being tested" (8:180). The validity of Section I was established by using a previously accepted survey instrument. Validity of Sections II and III was established through the use of the actual terminology and evaluation methods used in the source selection process. Respondents are faced with the same trade-off decisions when actually participating in a source selection.

Conclusion

The purpose of this chapter was to provide the methodology used to answer the investigative questions supporting the research objective. Table 5 describes the methods used to answer each investigative question. This chapter has discussed the methodology of collecting, organizing and analyzing the data used to accomplish the research objective addressed by this thesis. The next chapter reports the results of the study.

Table 5

Method of Answering Investigative Questions

Investigative Questions (IQ)	Methods Used to Answer IQ
1) What is the risk propensity of the source selection participants?	1) Section I of the survey was used.
2) How do source selection participants trade-off performance versus risk?	2) Section II and III of the survey were used. (Friedman test, median values)
3) Does risk propensity influence the trade-off decision?	3) Sections II & III of survey were used. (Results of IQ2, Spearman rank corr.)
4) Does the performance versus risk trade-off decision vary based on the item being evaluated?	4) Section II of the survey was used. (Results of IQ2 & IQ3, Spearman rank corr.)
5) To what degree are color-risk ratings preferred over one another ?	5) Section III of the survey was used. (Median values)

IV. Results

This chapter presents the results of the analysis of the survey data. The chapter describes the sample surveyed, explains why some responses were not used in the analysis, and the demographics of the respondents. The results are then presented for each applicable investigative question. The statistical results associated with each question are presented.

Survey Target Sample and Responses

The target sample was personnel currently stationed at Wright-Patterson Air Force Base OH (WPAFB) Aeronautical Systems Center (ASC) who had participated in a source selection. The sample of 202 people was identified by the Request For Proposal (RFP) and Source Selection Support Program Office at WPAFB.

Of the 202 surveys mailed, 80 surveys were returned by the deadline. Seven of the 202 surveys mailed were returned unopened due to inaccurate mailing addresses or due to transfer of personnel. Of the 80 surveys returned, four were unusable because the survey had not been filled out completely. The resulting data set consisted of 76 returned, correctly filled-out surveys. This is a response rate of 40%.

Figures 4, 5 and 6 show the demographic information collected on the responding individuals. The data indicates

that the majority of respondents had participated in the source selection as an item captain, area chief, or evaluator (81.6%). The largest responding group were those presently working as program managers (32.9%). Over half of the respondents were lower level managers or workers (O-1 to O-3, GS-12 and below). The remaining group was primarily middle level managers (O-4 and O-5, GS-13 to GM-14). The average acquisition experience of the respondents was 11.0 years. The range of experience was from a minimum of 1 year to a maximum of 34 years. Based on the demographic characteristics of the sample, the respondents are reflective of the population.

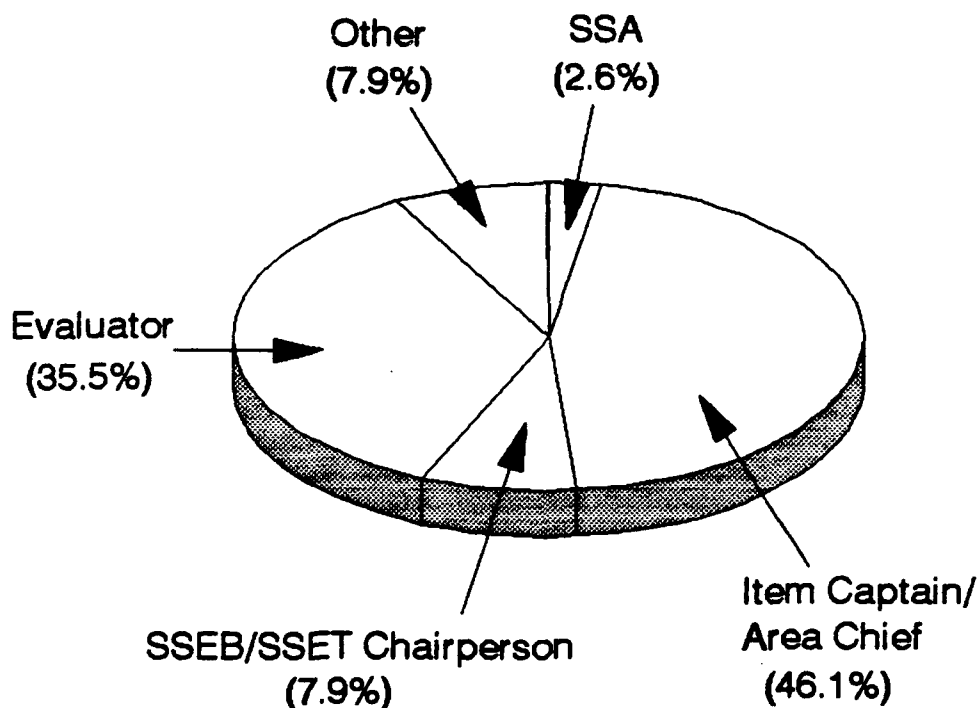


Figure 4
Highest Position Held in a Source Selection

Investigative Questions

1. What is the risk propensity of the source selection participants?
2. How do source selection participants trade-off performance versus risk?
3. Does risk propensity influence the trade-off decision?
4. Does the performance versus risk trade-off decision vary based on the item being evaluated?
5. To what degree are color-risk ratings preferred over one another?

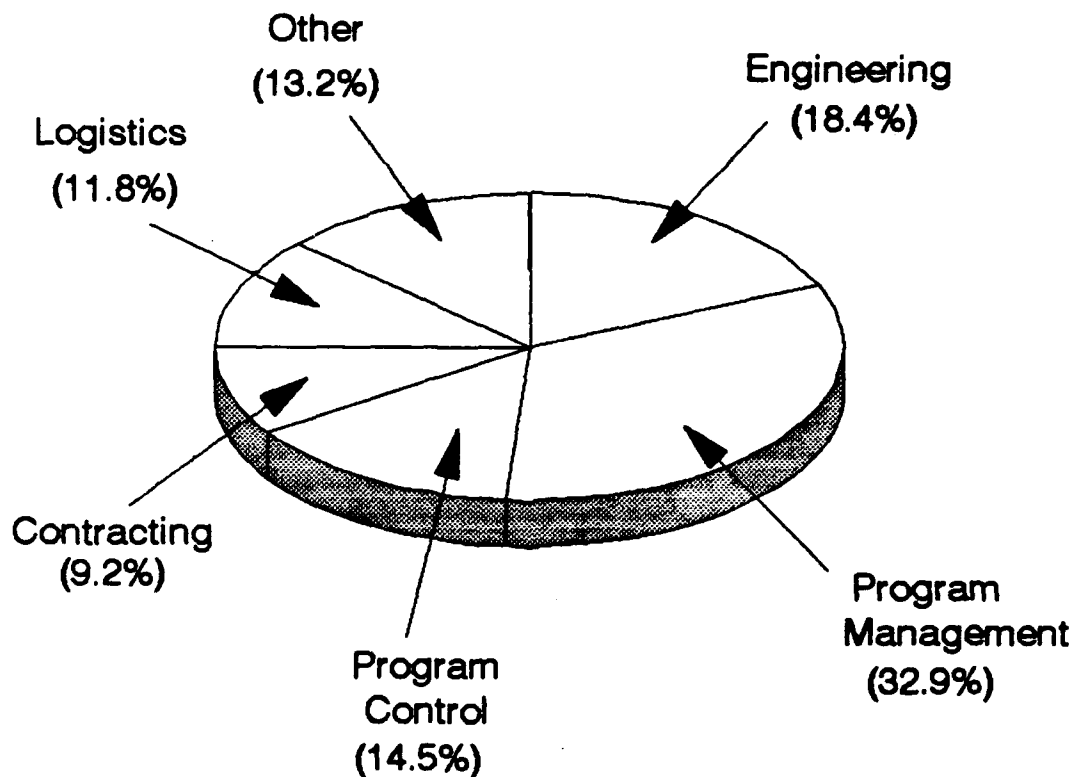


Figure 5
Acquisition Specialty

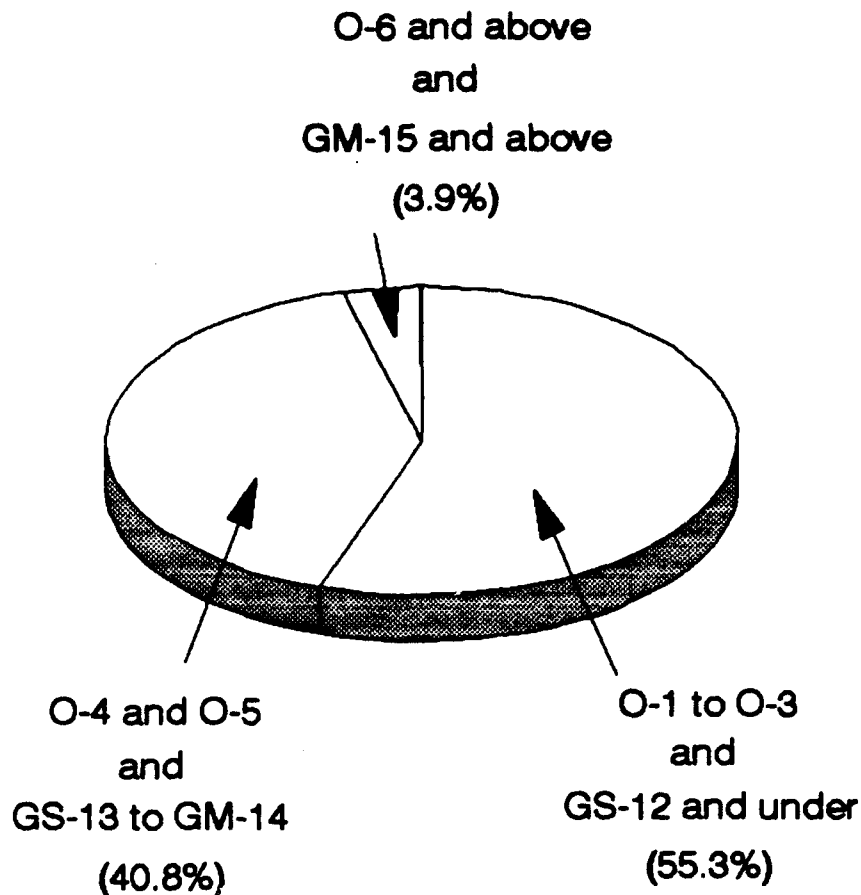


Figure 6
Military Rank and Civilian Grade

Risk Propensity Categorization. What is the risk propensity of the source selection participants sampled?

The assessment in survey Section I resulted in the identification of 23 risk averters, 29 risk neutrals, and 24 risk takers. The assessment scale ranged in integers from -6 to 6. A score of zero resulted in a risk propensity assignment of risk neutral. A negative score resulted in a risk propensity assignment of risk averter, while a positive

score resulted in a risk propensity assignment of risk taker. The histogram in Figure 7 shows the distribution of raw scores for the entire sample.

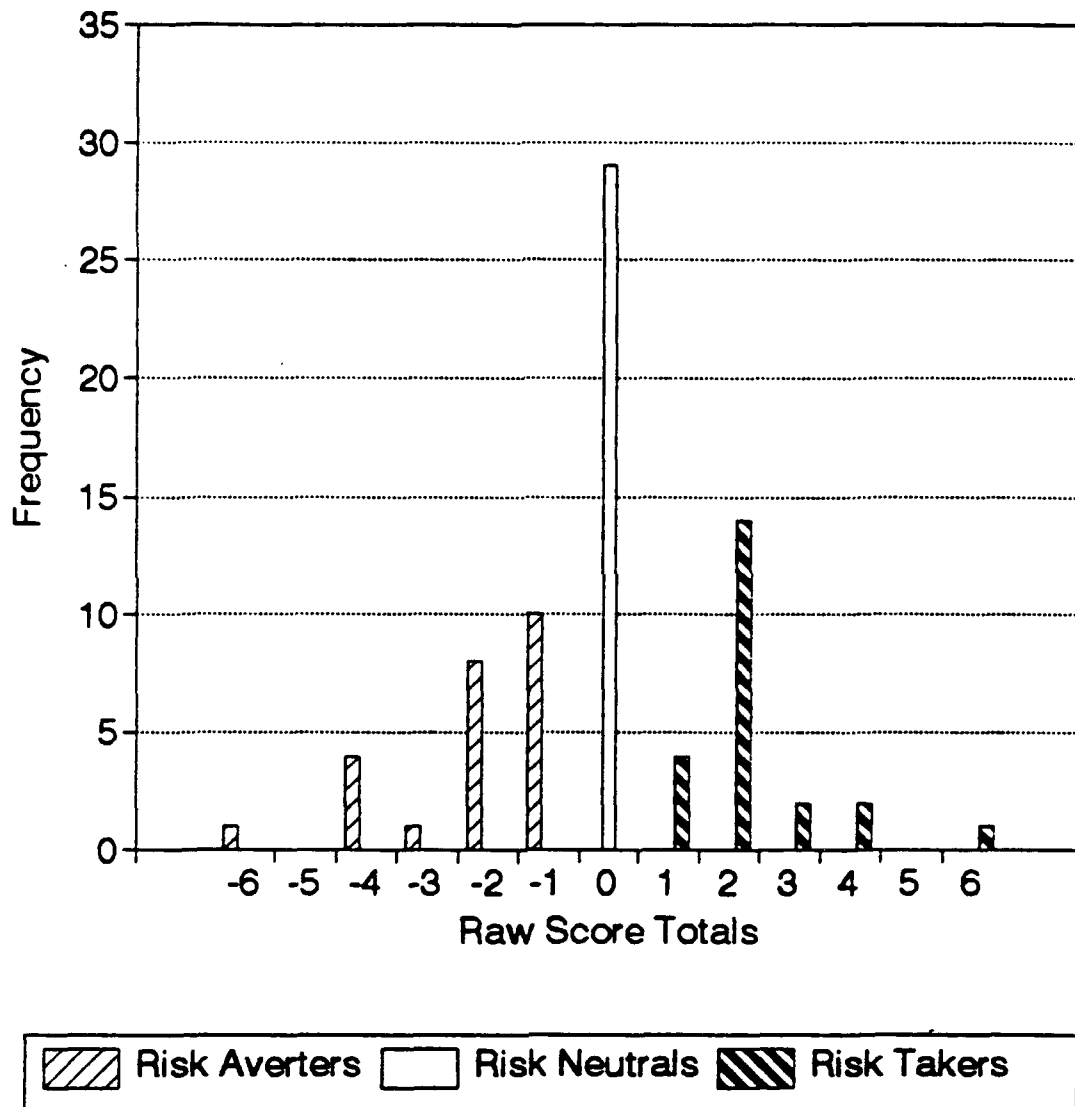


Figure 7
Risk Propensity Distribution

Performance/Risk Trade-Off. How do source selection participants trade-off performance versus risk? Figure 8 shows the results of color-risk rating ranks.

	Blue	Green	Yellow
High	5	7	9
Moderate	2(tie)	4	8
Low	1	2(tie)	6

Figure 8
Color-Risk Rating Ranks

Analysis shows that a definite rank order exists among the color-risk ratings ($\alpha = 0.05$). The relationships shown above affirm that lower risks are preferred to higher risks and blue ratings are preferred to green ratings, which are preferred to yellow ratings. The trend is to prefer color-risk ratings in the lower left hand corner of the source selection evaluation matrix. The Blue-Moderate and Green-Low color-risk ratings were not statistically different from one another ($\alpha = 0.05$). Table 6 shows the results of the

Table 6

Friedman Test Color-Risk Rankings
for The Entire Sample, Technical Capability Item Summary
(Note: rankings that are not significantly
different are identified by ***)

1)	Blue Low	76
2t)	Blue Moderate***	199
2t)	Green Low***	204
4)	Green Moderate	323
5)	Blue High	395
6)	Yellow Low	460
7)	Green High	512
8)	Yellow Moderate	567
9)	Yellow High	682
Level Discriminator		
($\alpha = 0.05$): 22.08		

Friedman test. Appendix B contains the formulas and calculations used in the Friedman's test.

A rank order of color-risk ratings for the entire sample for the technical capability item summary was constructed using an ordinal scale of pairwise comparisons. The results are shown in Table 7. Table 8 shows the preferences between color-risk rating pairs used to construct the rank order. Comparison of the ordinal scale rank order to the Friedman test rank order show that the relative order among color-risk ratings is the same. The only exception is that the Yellow-Low and Green-High ratings are tied. The Spearman's rank correlation indicated that

Table 7
Ordinal Scale Color-Risk Rankings
for The Entire Sample, Technical Capability Item Summary

1)	Blue Low
2t)	Blue Moderate
2t)	Green Low
4)	Green Moderate
5)	Blue High
6t)	Yellow Low
6t)	Green High
8)	Yellow Moderate
9)	Yellow High

Table 8
Color-Risk Pairing Preferences
for the Entire Sample

Relationship	Preference	Median
Blue High - Green Moderate	Green Moderate	5
Green Low - Blue High	Green Low	2
Blue High - Yellow Low	Blue High	3
Yellow Moderate - Green High	Green High	5
Yellow Low - Green High	NONE	4
Blue Moderate - Yellow Low	Blue Moderate	2
Yellow Low - Green Moderate	Green Moderate	5
Green Low - Blue Moderate	NONE	4
Blue High - Yellow Moderate	Blue High	3

the rankings were statistically the same ($r = 0.9958$).
Arriving at the same rank order using two different methods
adds to the reliability of establishing the true rank order

of color-risk ratings used in the source selection evaluation matrix.

Risk Propensity and Trade-Off Decisions. Does risk propensity influence the trade-off decision? Risk propensity does not influence the trade-off decision. Table 9 shows the rank orders established by risk propensity for the technical capability item summary using the Friedman test. The color-risk rank order is identical for risk averters and risk neutrals. Risk takers' rank order differs from the other two categories only in that there is difference between the Yellow-Low and Green-High ratings. Appendix B contains the formulas, calculations, and the level discriminator used in the Friedman's test to establish rank orders for all risk propensity categories.

Spearman rank correlations were calculated for all the combinations of risk propensity. The result of the Spearman rank correlations is that there is a high degree of correlation among risk propensity categories. Table 10 shows the Spearman rank correlation values.

Item Summary and Trade-Off Decisions. Does the performance versus risk trade-off decision vary based on the item being evaluated? The trade-off decision based on

Table 9

Color-Risk Ranking by Risk Propensity,
Technical Capability Item Summary

Risk Averter	Risk Neutral	Risk Taker
1) Blue Low	1) Blue Low	1) Blue Low
2t) Blue Moderate	2t) Blue Moderate	2t) Blue Moderate
2t) Green Low	2t) Green Low	2t) Green Low
4) Green Moderate	4) Green Moderate	4) Green Moderate
5) Blue High	5) Blue High	5) Blue High
6) Yellow Low	6) Yellow Low	6t) Yellow Low
7) Green High	7) Green High	6t) Green High
8) Yellow Moderate	8) Yellow Moderate	8) Yellow Moderate
9) Yellow High	9) Yellow High	9) Yellow High

Table 10

Spearman Rank Correlations for Risk Propensity Categories,
Technical Capability Item Summary

	Risk Averter	Risk Neutral
Risk Neutral	0.9833	N/A
Risk Taker	1.0000	0.9833

performance versus risk does not vary according to item summary level.

Table 11 shows the results of the Friedman test color-risk rankings by summary areas. The Spearman rank correlation for item summary levels is 1.0000. The rank order is exactly the same for each item summary level.

Table 11

Comparison of Item Summary Levels
on Color-Risk Rankings Using the Friedman Test
(Note: rankings that are not significantly
different are identified by ***)

Technical Capability:		Management:	
Blue Low	76	Blue Low	76
Blue Moderate***	199	Green Low***	201
Green Low***	204	Blue Moderate***	207
Green Moderate	323	Green Moderate	334
Blue High	395	Blue High	394
Yellow Low	460	Yellow Low	447
Green High	512	Green High	516
Yellow Moderate	567	Yellow Moderate	561
Yellow High	682	Yellow High	684
Level Discriminator		Level Discriminator	
($\alpha = 0.05$):	22.08	($\alpha = 0.05$):	22.99

Degree of Preference. To what degree are color-risk ratings preferred over one another? Table 12 shows the preference among various color-risk rating pairs. No preference exists between the comparison of Green-Low to Blue-Moderate ratings and Yellow-Low to Green-High ratings. The greatest difference in preferences occur when comparing the Green-Low to Blue-High ratings and the Blue-Moderate to Yellow-Low ratings. These comparisons showed moderate preferences. The remaining five comparisons showed only slight preferences among the color-risk pairs. Histograms

of the responses for color-risk preferences are provided in Appendix C.

Table 12
Summary of Preferences Among
Color-Risk Ratings Based Upon Median Values

A	B	Preference Comparison
Blue-High	Green-Moderate	B slightly to A
Green-Low	Blue-High	A moderately to B
Blue-High	Yellow-Low	A slightly to B
Yellow-Moderate	Green-High	B slightly to A
Yellow-Low	Green-High	None
Blue-Moderate	Yellow-Low	A moderately to B
Yellow-Low	Green-Moderate	B slightly to A
Green-Low	Blue-Moderate	None
Blue-High	Yellow-Moderate	A slightly to B

Summary

The analysis above has been used to answer the five investigate questions first posed in Chapter I. The results will be used to draw conclusions in Chapter V. The demographics of our sample were presented. The respondents were categorized into risk propensity groups. A rank order of color-risk ratings was established for the entire sample using Friedman's test. Rank orders of color-risk ratings were also found through the use of ordinal scale comparisons. Once both rankings were established, Spearman's rank correlations were used to compare rank orders.

Next, rank orders were established for risk propensity groups using the Friedman test. The rank orders were compared using the Spearman rank correlations. Rank orders were also compared across item summary levels using the Friedman test. These rank orders were compared using the Spearman rank correlation. Finally, the pairwise ranking preferences were compared using an appropriate ordinal scale.

The following summary highlights significant results in the analysis. The following order of color-risk ratings was established: Blue-Low, Green-Low/Blue-Moderate, Green-Moderate, Blue-High, Yellow-Low, Green-High, Yellow-Moderate, and Yellow-High. No difference between Green-Low and Blue-Moderate was found using the Friedman test or the pairwise comparison. This rank order structure remained unchanged, for the most part, for all risk propensity categories and for both item summary levels. The Spearman's rank correlations showed high correlations for all combinations of risk propensity categories and for both item summary levels. Examination of median values indicated that for most of the pairwise rankings one choice was only slightly preferred to the other.

Chapter 5 will provide conclusions based on the results presented in this chapter. Recommendations for topics of further study will also be discussed.

V. Conclusions and Recommendations

Introduction

This chapter discusses the importance of the research, reviews the methodology, presents the major findings, discusses the implications and limitations of the findings, and culminates in recommendations for source selection and future study.

Each year the Air Force awards weapon system contracts worth billions of dollars using the source selection process. In the source selection, performance and risk assessments are evaluated to award a contract to the proposal that gives the best overall value. The purpose of this research was to investigate the performance/risk trade-off in the source selection decision making process. The results of these decisions will affect the military capability and readiness of the Air Force.

Review of Methodology

Air Force (AF) acquisition personnel stationed at Aeronautical Systems Center (ASC), Wright-Patterson AFB, OH, who had participated in a source selection were surveyed. These people are representative group of all AF who make decisions during a source selection. The survey required respondents to rank various color-risk rating combinations

used in the source selection process from most to least preferred. The rankings were used to establish the rank order among color-risk ratings. Respondents also indicated their degree of preference between color-risk rating pairs using an ordinal scale. Use of the ordinal scale provided another means to establish the rank order. The new rank order was compared to the first rank order and demonstrated the reliability of the survey. Comparisons were made for two specific areas (item summary levels): technical capability and management. The survey contained questions to categorize the respondents according to risk propensities (risk avoider, risk neutral and risk taker) to measure the effects risk propensity has on the color-risk rank order.

Rank orders were statistically established using the Friedman test ($\alpha=0.05$). A rank order was established using the results of the median value for pairwise comparisons of color-risk ratings. The Spearman correlation test was used to measure the similarities in the various rank orders.

Major Findings

A definite rank order exists among the color-risk rating combinations. The same rank order was found using both the Friedman test and the ordinal scale method.

Risk propensity does not change the relative rank order of the color-risk ratings. The only exception is that risk takers do not show a preference between the Yellow-Low and

Green-High ratings, while risk averters and risk neutrals prefer the Yellow-Low rating.

The item being evaluated does not change the relative rank order of the color-risk ratings. The rank orders established using the Friedman test for the technical capability and management item summaries were identical (Spearman correlation = 1.0000).

The ordinal scale pairwise comparisons showed that no preference existed between Blue-Moderate/Green-Low and Green-High/Yellow-Low. A moderate preference exists for Blue-Moderate to Yellow-Low and Green-Low to Blue-High. All other combinations examined only exhibited slight preferences.

Table 13 summarizes the rank orders found for the various conditions (item summary level and risk propensity) and methods to establish rank order (Friedman test or ordinal scale/median value method). Analysis of the various rank order structures indicated that a definite uniform rank order structure exists. Further analysis shows that regardless of the variables studied (risk propensity and item being evaluated), the rank order did not change.

Implications of the Findings

The findings of the research can be applied to the areas of personnel assignment for source selections and decision support systems.

Table 13

Summarization of Rank Order Findings

	Ordinal Scale Ranks: Tech Cap	Friedman Test Ranks: Tech Cap	Friedman Test Ranks: Mngmnt	Friedman Test Ranks: Averters	Friedman Test Ranks: Neutrals	Friedman Test Ranks: Takers
Blue-Low	1	1	1	1	1	1
Blue-Moderate	2(tie)	2(tie)	2(tie)	2(tie)	2(tie)	2(tie)
Green-Low	2(tie)	2(tie)	2(tie)	2(tie)	2(tie)	2(tie)
Green-Moderate	4	4	4	4	4	4
Blue-High	5	5	5	5	5	5
Yellow-Low	6(tie)	6	6	6	6	6(tie)
Green-High	6(tie)	7	7	7	7	6(tie)
Yellow-Moderate	8	8	8	8	8	8
Yellow-High	9	9	9	9	9	9

The findings of the research show that individual risk propensities do not influence the performance-risk trade-off decisions. Some program directors may feel risk propensity is an important factor to consider when selecting people for participation in a source selection decision making role. The research indicates that individual risk propensity does not influence the decision of evaluators when choosing among evaluated proposals based on color-risk ratings. When faced with making decisions based on color-risk ratings, one can expect that the decision makers will lay their personal

attitudes aside and arrive at a decision that can be predicted with the rank order established by this research.

Since a uniform rank order was found, it could be used as a basis for a decision support system for source selections. In generating item level summaries, a mathematical weighting system could be employed at factor and area levels to arrive at an aggregate color-risk rating. Using this system, all the factors requiring analysis could be color-risk rated individually. The results would then be input into the decision support system and the area, item and overall color-risk ratings generated according to a weighting algorithm contained in the decision support system. Objective, measurable criterion, not intuition, would determine higher level color-risk ratings. Friedman tests could be used to derive the interval (weighting) among color-risk ratings used in the algorithm.

Using such a decision support system, overall color-risk ratings of proposals would be determined from lower level assessments. Comparing color-risk ratings of the evaluated proposals would provide comparative scores for proposals that could be used in choosing a winner according to the color-risk rating rankings found by this research.

This approach can be used in any situation where a trade-off between two scales is necessary to arrive at a decision. Aircraft maintainers could use a system like this to determine which planes to fix based upon logistics

constraints (personnel, parts, time, etc.) and mission readiness requirements (ie. 100% of squadron aircraft flyable, but only 50% mission capable versus 75% of squadron aircraft flyable and mission capable with the remaining 25% down). The implementation would require establishing a rank order among the combinations of variables and determining the appropriate governing algorithm.

Limitations of the Findings

The findings of this thesis are limited by the sample surveyed. The survey was administered to personnel at ASC and the results may not be perfectly reflective of all product centers. The business environments at various product centers is different because of the type of weapon systems procured. ASC buys aircraft, in large numbers, worth billions of dollars, where Space and Missile Center buys satellites, in small numbers, worth millions of dollars. The size of the purchase invokes regulatory constraints as well as managerial opportunities that may not be present elsewhere.

The findings are also limited to source selections involving weapon systems, it is not expandable to base level and spares contracting. Base level and spares contracting personnel were not surveyed to develop the color-risk rank order. Base level contracting typically deals with very

small dollar amounts, has lower relative risk, and is subject to less scrutiny than weapon system contracting.

The method of assessing risk propensity also limits the findings. The respondents were asked to choose between alternatives in a lottery type setting. The dollar values associated with these choices are more indicative of personal than professional business situations. This could alter the view a program director has of a person's risk propensity because people can behave differently when dealing with risk in their personal and professional lives (15:176).

Recommendations

This thesis was the first attempt to examine the preference of color-risk ratings in the source selection environment. Recommendations from this research consist of applying results to actual source selections, expansion on the basic framework of this study, and investigation of other color-risk rating relationships.

Recommendation 1: The decision support system presented earlier in this chapter could be developed and applied to an actual source selection. This thesis conducted an ordinal scale study of the color-risk rating relationships to characterize the rank structure. Interval level data for a decision support system would need to be developed to enhance the algorithm. The decision support

system would also have to build the interrelationships among factors, areas, items and overall ratings.

Recommendation 2: This research examined the relationship of technical capability and management item summary levels. Further research should examine other item summary levels (cost, schedule, contractual, financial, and past performance) and the overall color-risk ratings to compare findings. Broader research on other item areas will provide a better understanding of all areas considered in the source selection.

Recommendation 3: Air Force acquisition personnel were the population of this study, with Aeronautical Systems Center serving as the target sample. Other product centers should be studied to examine the effects on source selection decisions, relating to color-risk ratings, to account for differences in technological challenges and historical contracting practices. This study will show whether or not the findings of this study are generalizable. It also has the potential to identify trends in risk propensity of product centers.

Recommendation 4: An unsolicited comment from a survey response stated that the acquisition business is about taking risks. In the present acquisition environment, it could be argued that the goal is to minimize technical, cost and schedule overruns in acquiring weapon systems. It could also be argued that the goal is to provide the most

technically advanced and capable weapon systems. These two diametric perspectives on acquisition have the potential to influence source selection decisions. An examination of individual perceptions on the goals of acquisition can yield further insight to the trade-offs made in source selections.

Recommendation 5: Noffsinger's study showed that Technical Risk demonstrated the highest correlation with award decisions (18:79). His studies compared all winning proposals with all losing proposals. The results of this study indicate that color influences performance-risk trade-off decisions. Further research should study the affects of color and risk ratings on actual competitive groups; not on an aggregated data base, as Noffsinger did. Study of ratings in this manner will reveal how performance and risk were traded-off between competing proposals. For example, Noffsinger points out that three Yellow-Low proposals were awarded contracts (18:57-58). This fact raises the question of "who was the competition and how did their color-risk ratings affect the award decision?"

Recommendation 6: This study included all possible color-risk ratings that can receive an award (non-Red color ratings). Noffsinger's study demonstrated that in 82 base level source selections there were no proposals rated overall as Blue-Moderate, Blue-High and Red-Low (18:57-58). The question arises as to whether these color-risk ratings have real meaning in the source selection environment or are

they just rare occurrences. A study can be conducted to investigate this phenomena among other product center source selection decisions. The results have the potential to modify the rank order preference of color-risk ratings found in this study by eliminating "unrealistic" ratings.

Recommendation 7: This study was conducted in an environment where the Department of Defense's (DoD) budget was being cut and Congressional oversight was acute. If the acquisition environment conditions change (to those found in the Reagan Administration for example), the findings of this study may no longer be applicable and a re-examination of this topic should be undertaken.

Recommendation 8: The research findings show that according to the color-risk rating preferences, source selection participants prefer proposals that meet or exceed technical requirements at low risk. A question that lingers is the connotation associated with low risk in the DoD acquisition environment. Does low risk to an acquisition professional mean the same to a defense contractor, Congressmen, government auditor, or the average American? A study should be undertaken to establish if the connotated definition of low risk is the same among these groups.

Appendix A: Survey

Thank you for participating in this study. We realize that your time is extremely valuable and greatly appreciate the time you have taken to answer this survey. This survey will require approximately 15 minutes to complete. The purpose of this research effort is to enhance the Source Selection process. The results will provide insight on the role Risk Management plays in Source Selection decisions.

You have been selected as a participant because of your involvement in prior Source Selections. Your name was provided by our Sponsor, Aeronautical Systems Center's RFP and Source Selection Support Program Office (ASC/CYX). Your participation is completely voluntary. Please do not include your name on the survey so anonymity will be maintained.

Responses will not be analyzed on an individual basis. Individual responses will be grouped so survey results will be a reflection of the sample population. Findings will be published this September in AFIT thesis, AFIT/GSM/LAS/93S-18.

Again, thank you for your participation.

Section I

1. Which of the following would you prefer?

- A. An 80% chance of gaining \$4,000 and a 20% chance of gaining \$0
- B. A certain gain of \$3,200
- C. No preference

2. Which of the following would you prefer?

- A. A 25% chance of gaining \$3,200 and a 75% chance of gaining \$0
- B. A 20% chance of gaining \$4,000 and an 80% chance of gaining \$0
- C. No preference

3. Which of the following would you prefer?

- A. An 80% chance of losing \$4,000 and a 20% chance of losing \$0**
- B. A certain loss of \$3,200**
- C. No preference**

4. Which of the following would you prefer?

- A. A 25% chance of losing \$3,200 and a 75% chance of losing \$0**
- B. A 20% chance of losing \$4,000 and an 80% chance of losing \$0**
- C. No preference**

5. Which of the following would you prefer?

- A. A 90% chance of gaining \$3,000 and a 10% chance of gaining \$0**
- B. A 45% chance of gaining \$6,000 and an 55% chance of gaining \$0**
- C. No preference**

6. Which of the following would you prefer?

- A. A 90% chance of losing \$3,000 and a 10% chance of losing \$0**
- B. A 45% chance of losing \$6,000 and an 55% chance of losing \$0**
- C. No preference**

Section II

The following are the current AFR 70-15, Formal Source Selections for Major Acquisitions, and AFR 70-30, Streamlined Source Selection Procedures, definitions. They represent the official definitions of the color code ratings and proposal risk assessments. Please use these definitions for the next two sections.

COLOR RATINGS

BLUE (Exceptional)	Exceeds specified performance or capability in a beneficial way to the Air Force; and has a high probability of satisfying the requirement; and has no significant weakness.
GREEN (Acceptable)	Meets evaluation standards; and has good probability of satisfying the requirement; and any weaknesses can be readily corrected.
YELLOW (Marginal)	Fails to meet evaluation standards; or has low probability of satisfying the requirement; or has significant deficiencies but correctable.
RED (Unacceptable)	Fails to meet a minimum requirement (Not used in this survey.)

PROPOSAL RISK ASSESSMENTS

HIGH	Likely to cause significant serious disruption of schedule, increase in cost, or degradation of performance even with special contractor emphasis and close government monitoring.
MODERATE	Can potentially cause some disruption of schedule, increase in cost, or degradation of performance. However special contractor emphasis or close government monitoring will probably be able to overcome difficulties.
LOW	Has little potential to cause disruption of schedule, increase in cost, or degradation of performance. Normal contractor effort and normal government monitoring will probably be able to overcome difficulties.

The following table is the Source Selection Evaluation Matrix. It is a matrix that contains possible combinations of color rankings/proposal risk assessment pairs. Please rank the boxes according to your preferences in making a source selection decision. Number 1 and Number 9 have been entered to illustrate the procedure for completing this question. Feel free to change these rankings if you want. In ranking the pairs, Number 1 is your most preferred option while number 9 is your least preferred option. Ties are not allowed.

Please evaluate for Item Summary:

Technical Capability

COLOR RATING RISK	BLUE	GREEN	YELLOW
HIGH			9
MODERATE			
LOW	1		

Please evaluate for Item Summary:

Management

COLOR RATING RISK	BLUE	GREEN	YELLOW
HIGH			9
MODERATE			
LOW	1		

Section III - In this section, imagine yourself as the Source Selection Authority and each color rating/proposal risk assessment represents the technical capability item area ranking of competing proposals. Select the proposal you prefer and the degree to which you prefer it over the other proposal. Please circle a number on the scale.

A.

Color: Blue
Risk: High

1	2	3	4	5	6	7
Highly Prefer This Choice			No Preference			Highly Prefer This Choice

Color: Green
Risk: Moderate

B.

Color: Green
Risk: Low

1	2	3	4	5	6	7
Highly Prefer This Choice			No Preference			Highly Prefer This Choice

Color: Blue
Risk: High

C.

Color: Blue
Risk: High

1	2	3	4	5	6	7
Highly Prefer This Choice			No Preference			Highly Prefer This Choice

Color: Yellow
Risk: Low

D.

Color: Blue
Risk: Low

1	2	3	4	5	6	7
Highly Prefer This Choice			No Preference			Highly Prefer This Choice

Color: Green
Risk: Moderate

E.

Color: Yellow
Risk: Moderate

1	2	3	4	5	6	7
Highly Prefer This Choice			No Preference			Highly Prefer This Choice

Color: Green
Risk: High

F.

Color: Yellow
Risk: Low

1	2	3	4	5	6	7
Highly Prefer This Choice			No Preference			Highly Prefer This Choice

Color: Green
Risk: High

G.

Color: Blue
Risk: Moderate

1	2	3	4	5	6	7
Highly Prefer This Choice			No Preference			Highly Prefer This Choice

Color: Yellow
Risk: Low

H.

Color: Yellow

Risk: Low

1	2	3	4	5	6	7
Highly Prefer This Choice			No Preference			Highly Prefer This Choice

Color: Green

Risk: Moderate

I.

Color: Yellow

Risk: Moderate

1	2	3	4	5	6	7
Highly Prefer This Choice			No Preference			Highly Prefer This Choice

Color: Green

Risk: Low

J.

Color: Green

Risk: Low

1	2	3	4	5	6	7
Highly Prefer This Choice			No Preference			Highly Prefer This Choice

Color: Blue

Risk: Moderate

K.

Color: Blue

Risk: High

1	2	3	4	5	6	7
Highly Prefer This Choice			No Preference			Highly Prefer This Choice

Color: Yellow

Risk: Moderate

Section IV

1. What is your military rank/civilian grade? _____
2. How many total years of acquisition experience do you have?

3. Which acquisition specialty are you presently working in? (ie. program management, logistics, contracting, program control, etc.)

4. In your personal financial life, do you consider yourself:

A. risk taking B. risk neutral C. risk avoiding
5. In your professional life, do you consider yourself:

A. risk taking B. risk neutral C. risk avoiding

6. What is the highest position you have held in a source selection?

A. SSA

B. SSEB/SSET Chairperson

C. Item Captain/Area Chief

D. Evaluator

E. Other, please specify: _____

Please place in return envelope. Thank you for participating!



DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AERONAUTICAL SYSTEMS CENTER (AFMC)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

FROM: ASC/CY

13 MAY 1993.

SUBJ: Survey of Source Selection Participants

TO: Survey Participants

1. I support this AFIT thesis project which is sponsored by the RFP and Source Selection Support Program Office (ASC/CYX).
2. The attached survey evaluates AF Regulations 70-15 and 70-30 emphasis on the importance of identifying and evaluating risk in the source selection process. As a recipient of this survey, you are in a position to contribute to a research project investigating how risk is dealt with by source selection participants. The data collected will be used to help understand how one's attitude toward risk influences the decisions of source selection participants.
3. Please take 10-15 minutes to complete the attached survey and return it in the enclosed addressed envelope no later than 24 May 93. We request that you do not write your name on the survey, so your individual response will remain anonymous.
4. Your participation in this study is completely voluntary, but we would greatly appreciate your help. For further information, please contact faculty advisors for this research project, Lt Col Carl Templin, 54845, or Maj Kevin Grant, 54845.

ROBERT C. HELT
Colonel, USAF
Director, Program Management

- 2 Atch
1. Survey
2. Return Envelope

Appendix B: Friedman Test Results

Analysis for entire sample.

ORIGIN = 1

M = READPRN(SUMMARY)

cols(M) = 18

rows(M) = 76

I = 1 .. rows(M) J = 1 .. cols(M)

At this stage, we are calculating the sum of the ranks for each color-risk rating. This is accomplished by summing the columns of the matrix. SMBL stands for the sum of management blue low column. STBL stands for the sum of technical blue low column. (G=green, Y=yellow, M=moderate, H=high)

$SMBL = \sum_i M_{i,1}$	SMBL = 76	$STBL = \sum_i M_{i,10}$	STBL = 76
$SMBM = \sum_i M_{i,2}$	SMBM = 207	$STBM = \sum_i M_{i,11}$	STBM = 199
$SMBH = \sum_i M_{i,3}$	SMBH = 394	$STBH = \sum_i M_{i,12}$	STBH = 395
$SMGL = \sum_i M_{i,4}$	SMGL = 201	$STGL = \sum_i M_{i,13}$	STGL = 204
$SMGM = \sum_i M_{i,5}$	SMGM = 334	$STGM = \sum_i M_{i,14}$	STGM = 323
$SMGH = \sum_i M_{i,6}$	SMGH = 516	$STGH = \sum_i M_{i,15}$	STGH = 512
$SMYL = \sum_i M_{i,7}$	SMYL = 447	$STYL = \sum_i M_{i,16}$	STYL = 460
$SMYM = \sum_i M_{i,8}$	SMYM = 561	$STYM = \sum_i M_{i,17}$	STYM = 567
$SMYH = \sum_i M_{i,9}$	SMYH = 684	$STYH = \sum_i M_{i,18}$	STYH = 682

Analysis step to simplify calculations.

$S_1 = SMBL$	$S_5 = SMGM$	$S_{10} = STBL$	$S_{14} = STGM$
$S_2 = SMBM$	$S_6 = SMGH$	$S_{11} = STBM$	$S_{15} = STGH$
$S_3 = SMBH$	$S_7 = SMYL$	$S_{12} = STBH$	$S_{16} = STYL$
$S_4 = SMGL$	$S_8 = SMYM$	$S_{13} = STGL$	$S_{17} = STYM$
$S_9 = SMYH$		$S_{18} = STYH$	

Calculation of the test statistics.

Sum of the squares for the matrix elements. This term is the same for both management and technical ratings. The term $\text{cols}(M)/2$ is used because the file read in contains two sets of data; management and technical rankings.

$$A2 = \frac{\text{rows}(M) \cdot \frac{\text{cols}(M)}{2} \cdot \left(\frac{\text{cols}(M)}{2} + 1 \right) \cdot \frac{2 \cdot \text{cols}(M)}{2} + 1}{6}$$

$$A2 = 2.166 \cdot 10^4$$

Square of the column sums added together divided by the number of cases. B2M is for the management case. B2T is for the technical case.

$$K = 1 \dots 9$$

$$L = 10 \dots 18$$

$$B2M = \frac{1}{\text{rows}(M)} \cdot \left[\sum_K S_K^2 \right]$$

$$B2T = \frac{1}{\text{rows}(M)} \cdot \left[\sum_L S_L^2 \right]$$

$$B2M = 2.111 \cdot 10^4$$

$$B2T = 2.115 \cdot 10^4$$

Calculation of the F-statistic for the null hypothesis. (Null hypothesis is that there is no difference among the different color-risk ratings) The confidence level required is 95%. T2M is the F-statistic for management color risk rating and T2T is the F-statistic for technical color-risk rating.

$$T2M = \frac{(\text{rows}(M) - 1) \cdot B2M}{\frac{\text{rows}(M) \cdot \frac{\text{cols}(M)}{2} \cdot \frac{\text{cols}(M)}{2} + 1}{4} - B2M}$$

$$T2M = 548.309$$

$$T2T = \frac{(\text{rows}(M) - 1) \cdot B2T}{\frac{\text{rows}(M) \cdot \frac{\text{cols}(M)}{2} \cdot \frac{\text{cols}(M)}{2} + 1}{4} - B2T}$$

$$T2T = 600.889$$

Calculation of a 95% confidence level statistic.

$$k1 = \frac{\text{cols}(M) - 2}{2}$$

$$k1 = 8$$

$$k2 = k1 \cdot (\text{rows}(M) - 1)$$

$$k2 = 600$$

Using Statistix 4.0 and the values of k1 and k2 above for the degrees of freedom, the F-statistic value is 1.95. Since T2M and T2T are greater than the F-statistic for a 95% confidence interval, the null hypothesis is rejected. The comparison statistic is calculated to identify significant differences in rankings.

Comparison statistic. LevelM is the comparison statistic for the management color-risk rankings and LevelT is for the technical color-risk rankings.

$$\text{LevelM} = 1.95 \cdot \left[\frac{2 \cdot \text{rows}(M) \cdot (A2 - B2M)}{(\text{rows}(M) - 1) \cdot \left(\frac{\text{cols}(M)}{2} - 1 \right)} \right]^{\frac{1}{2}}$$

$$\text{LevelM} = 22.99$$

$$\text{LevelT} = 1.95 \cdot \left[\frac{2 \cdot \text{rows}(M) \cdot (A2 - B2T)}{(\text{rows}(M) - 1) \cdot \left(\frac{\text{cols}(M)}{2} - 1 \right)} \right]^{\frac{1}{2}}$$

$$\text{LevelT} = 22.078$$

Analysis for risk avoiders.

ORIGIN = 1

M = READPRN(AVOID)

cols(M) = 18

rows(M) = 23

I = 1 .. rows(M) J = 1 .. cols(M)

At this stage, we are calculating the sum of the ranks for each color-risk rating. This is accomplished by summing the columns of the matrix. S_{MBL} stands for the sum of management blue low column. S_{TBL} stands for the sum of technical blue low column. (G=green, Y=yellow, M=moderate, H=high)

$S_{MBL} = \sum_i M_{i,1}$	$S_{MBL} = 23$	$S_{TBL} = \sum_i M_{i,10}$	$S_{TBL} = 23$
$S_{MBM} = \sum_i M_{i,2}$	$S_{MBM} = 58$	$S_{TBM} = \sum_i M_{i,11}$	$S_{TBM} = 56$
$S_{MBH} = \sum_i M_{i,3}$	$S_{MBH} = 118$	$S_{TBH} = \sum_i M_{i,12}$	$S_{TBH} = 119$
$S_{MGL} = \sum_i M_{i,4}$	$S_{MGL} = 65$	$S_{TGL} = \sum_i M_{i,13}$	$S_{TGL} = 64$
$S_{MGM} = \sum_i M_{i,5}$	$S_{MGM} = 101$	$S_{TGM} = \sum_i M_{i,14}$	$S_{TGM} = 98$
$S_{MGH} = \sum_i M_{i,6}$	$S_{MGH} = 162$	$S_{TGH} = \sum_i M_{i,15}$	$S_{TGH} = 159$
$S_{MYL} = \sum_i M_{i,7}$	$S_{MYL} = 133$	$S_{TYL} = \sum_i M_{i,16}$	$S_{TYL} = 137$
$S_{MYM} = \sum_i M_{i,8}$	$S_{MYM} = 168$	$S_{TYM} = \sum_i M_{i,17}$	$S_{TYM} = 172$
$S_{MYH} = \sum_i M_{i,9}$	$S_{MYH} = 207$	$S_{TYH} = \sum_i M_{i,18}$	$S_{TYH} = 207$

Analysis step to simplify calculations.

$S_1 = S_{MBL}$	$S_5 = S_{MGM}$	$S_{10} = S_{TBL}$	$S_{14} = S_{TGM}$
$S_2 = S_{MBM}$	$S_6 = S_{MGH}$	$S_{11} = S_{TBM}$	$S_{15} = S_{TGH}$
$S_3 = S_{MBH}$	$S_7 = S_{MYL}$	$S_{12} = S_{TBH}$	$S_{16} = S_{TYL}$
$S_4 = S_{MGL}$	$S_8 = S_{MYM}$	$S_{13} = S_{TGL}$	$S_{17} = S_{TYM}$
$S_9 = S_{MYH}$		$S_{18} = S_{TYH}$	

Calculation of the test statistics.

Sum of the squares for the matrix elements. This term is the same for both management and technical ratings. The term $\text{cols}(M)/2$ is used because the file read in contains two sets of data; management and technical rankings.

$$A2 = \frac{\text{rows}(M) \cdot \frac{\text{cols}(M)}{2} \cdot \left(\frac{\text{cols}(M)}{2} + 1 \right) \cdot \left(2 \cdot \frac{\text{cols}(M)}{2} + 1 \right)}{6}$$

$$A2 = 6.555 \cdot 10^3$$

Square of the column sums added together divided by the number of cases. B2M is for the management case. B2T is for the technical case.

$$K = 1 \dots 9$$

$$L = 10 \dots 18$$

$$B2M = \frac{1}{\text{rows}(M)} \cdot \left[\sum_K (S_K)^2 \right]$$

$$B2T = \frac{1}{\text{rows}(M)} \cdot \left[\sum_L (S_L)^2 \right]$$

$$B2M = 6.402 \cdot 10^3$$

$$B2T = 6.435 \cdot 10^3$$

Calculation of the F-statistic for the null hypothesis. (Null hypothesis is that there is no difference among the different color-risk ratings) The confidence level required is 95%. T2M is the F-statistic for management color risk rating and T2T is the F-statistic for technical color-risk rating.

$$T2M = \frac{(\text{rows}(M) - 1) \cdot B2M}{\frac{A2}{B2M} \cdot \frac{\text{rows}(M) \cdot \frac{\text{cols}(M)}{2} \cdot \left(\frac{\text{cols}(M)}{2} + 1 \right)^2}{4}}$$

$$T2M = 176.601$$

$$T2T = \frac{(\text{rows}(M) - 1) \cdot B2T}{\frac{A2}{B2T} \cdot \frac{\text{rows}(M) \cdot \frac{\text{cols}(M)}{2} \cdot \left(\frac{\text{cols}(M)}{2} + 1 \right)^2}{4}}$$

$$T2T = 231.367$$

Calculation of a 95% confidence level statistic.

$$k1 = \frac{\text{cols}(M) - 2}{2}$$

$$k1 = 8$$

$$k2 = k1 \cdot (\text{rows}(M) - 1)$$

$$k2 = 176$$

Using Statistix 4.0 and the values of k1 and k2 above for the degrees of freedom, the F-statistic value is 1.95. Since T2M and T2T are greater than the F-statistic for a 95% confidence interval, the null hypothesis is rejected. The comparison statistic is calculated to identify significant differences in rankings.

Comparison statistic. LevelM is the comparison statistic for the management color-risk rankings and LevelT is for the technical color-risk rankings.

$$\text{LevelM} = 1.95 \cdot \left[\frac{2 \cdot \text{rows}(M) \cdot (A2 - B2M)}{(\text{rows}(M) - 1) \cdot \left(\frac{\text{cols}(M)}{2} - 1 \right)} \right]^{\frac{1}{2}}$$

$$\text{LevelM} = 12.326$$

$$\text{LevelT} = 1.95 \cdot \left[\frac{2 \cdot \text{rows}(M) \cdot (A2 - B2T)}{(\text{rows}(M) - 1) \cdot \left(\frac{\text{cols}(M)}{2} - 1 \right)} \right]^{\frac{1}{2}}$$

$$\text{LevelT} = 10.913$$

Analysis for risk neutrals.

ORIGIN = 1

M = READPRN(NEUTRAL)

cols(M) = 18

rows(M) = 29

I = 1 .. rows(M) J = 1 .. cols(M)

At this stage, we are calculating the sum of the ranks for each color-risk rating. This is accomplished by summing the columns of the matrix. SMBL stands for the sum of management blue low column. STBL stands for the sum of technical blue low column. (G=green, Y=yellow, M=moderate, H=high)

$SMBL = \sum_i M_{i,1}$	SMBL = 29	$STBL = \sum_i M_{i,10}$	STBL = 29
$SMBM = \sum_i M_{i,2}$	SMBM = 80	$STBM = \sum_i M_{i,11}$	STBM = 78
$SMBH = \sum_i M_{i,3}$	SMBH = 152	$STBH = \sum_i M_{i,12}$	STBH = 155
$SMGL = \sum_i M_{i,4}$	SMGL = 73	$STGL = \sum_i M_{i,13}$	STGL = 74
$SMGM = \sum_i M_{i,5}$	SMGM = 129	$STGM = \sum_i M_{i,14}$	STGM = 126
$SMGH = \sum_i M_{i,6}$	SMGH = 196	$STGH = \sum_i M_{i,15}$	STGH = 198
$SMYL = \sum_i M_{i,7}$	SMYL = 170	$STYL = \sum_i M_{i,16}$	STYL = 171
$SMYM = \sum_i M_{i,8}$	SMYM = 215	$STYM = \sum_i M_{i,17}$	STYM = 213
$SMYH = \sum_i M_{i,9}$	SMYH = 261	$STYH = \sum_i M_{i,18}$	STYH = 261

Analysis step to simplify calculations.

$S_1 = SMBL$	$S_5 = SMGM$	$S_{10} = STBL$	$S_{14} = STGM$
$S_2 = SMBM$	$S_6 = SMGH$	$S_{11} = STBM$	$S_{15} = STGH$
$S_3 = SMBH$	$S_7 = SMYL$	$S_{12} = STBH$	$S_{16} = STYL$
$S_4 = SMGL$	$S_8 = SMYM$	$S_{13} = STGL$	$S_{17} = STYM$
$S_9 = SMYH$		$S_{18} = STYH$	

Calculation of the test statistics.

Sum of the squares for the matrix elements. This term is the same for both management and technical ratings. The term $\text{cols}(M)/2$ is used because the file read in contains two sets of data; management and technical rankings.

$$A2 = \frac{\text{rows}(M) \cdot \frac{\text{cols}(M)}{2} \cdot \left(\frac{\text{cols}(M)}{2} + 1 \right) \cdot \left(2 \cdot \frac{\text{cols}(M)}{2} + 1 \right)}{6}$$

$$A2 = 8.265 \cdot 10^3$$

Square of the column sums added together divided by the number of cases. B2M is for the management case. B2T is for the technical case.

$$K = 1 \dots 9$$

$$L = 10 \dots 18$$

$$B2M = \frac{1}{\text{rows}(M)} \cdot \left[\sum_K S_K^2 \right]$$

$$B2T = \frac{1}{\text{rows}(M)} \cdot \left[\sum_L S_L^2 \right]$$

$$B2M = 8.068 \cdot 10^3$$

$$B2T = 8.077 \cdot 10^3$$

Calculation of the F-statistic for the null hypothesis. (Null hypothesis is that there is no difference among the different color-risk ratings) The confidence level required is 95%. T2M is the F-statistic for management color risk rating and T2T is the F-statistic for technical color-risk rating.

$$T2M = \frac{(\text{rows}(M) - 1) \cdot B2M}{\frac{\text{rows}(M) \cdot \frac{\text{cols}(M)}{2} \cdot \frac{\text{cols}(M)}{2} + 1}{4}} \cdot \frac{A2}{B2M}$$

$$T2M = 219.526$$

$$T2T = \frac{(\text{rows}(M) - 1) \cdot B2T}{\frac{\text{rows}(M) \cdot \frac{\text{cols}(M)}{2} \cdot \left(\frac{\text{cols}(M)}{2} + 1 \right)}{4}} \cdot \frac{A2}{B2T}$$

$$T2T = 231.339$$

Calculation of a 95% confidence level statistic.

$$k1 = \frac{\text{cols}(M) - 2}{2}$$

$$k1 = 8$$

$$k2 = k1 \cdot (\text{rows}(M) - 1)$$

$$k2 = 224$$

Using Statistix 4.0 and the values of k1 and k2 above for the degrees of freedom, the F-statistic value is 1.95. Since T2M and T2T are greater than the F-statistic for a 95% confidence interval, the null hypothesis is rejected. The comparison statistic is calculated to identify significant differences in rankings.

Comparison statistic. LevelM is the comparison statistic for the management color-risk rankings and LevelT is for the technical color-risk rankings.

$$\text{LevelM} = 1.95 \cdot \left[\frac{2 \cdot \text{rows}(M) \cdot (A2 - B2M)}{(\text{rows}(M) - 1) \cdot \left(\frac{\text{cols}(M)}{2} - 1 \right)} \right]^{\frac{1}{2}}$$

$$\text{LevelM} = 13.921$$

$$\text{LevelT} = 1.95 \cdot \left[\frac{2 \cdot \text{rows}(M) \cdot (A2 - B2T)}{(\text{rows}(M) - 1) \cdot \left(\frac{\text{cols}(M)}{2} - 1 \right)} \right]^{\frac{1}{2}}$$

$$\text{LevelT} = 13.6$$

Analysis for risk takers.

ORIGIN = 1

M = READPRN(RISKY)

cols(M) = 18 rows(M) = 24

I = 1 .. rows(M) J = 1 .. cols(M)

At this stage, we are calculating the sum of the ranks for each color-risk rating. This is accomplished by summing the columns of the matrix. SMBL stands for the sum of management blue low column. STBL stands for the sum of technical blue low column. (G=green, Y=yellow, M=moderate, H=high)

$SMBL = \sum_i M_{i,1}$	$SMBL = 24$	$STBL = \sum_i M_{i,10}$	$STBL = 24$
$SMBM = \sum_i M_{i,2}$	$SMBM = 69$	$STBM = \sum_i M_{i,11}$	$STBM = 65$
$SMBH = \sum_i M_{i,3}$	$SMBH = 124$	$STBH = \sum_i M_{i,12}$	$STBH = 121$
$SMGL = \sum_i M_{i,4}$	$SMGL = 63$	$STGL = \sum_i M_{i,13}$	$STGL = 66$
$SMGM = \sum_i M_{i,5}$	$SMGM = 104$	$STGM = \sum_i M_{i,14}$	$STGM = 99$
$SMGH = \sum_i M_{i,6}$	$SMGH = 158$	$STGH = \sum_i M_{i,15}$	$STGH = 155$
$SMYL = \sum_i M_{i,7}$	$SMYL = 144$	$STYL = \sum_i M_{i,16}$	$STYL = 152$
$SMYM = \sum_i M_{i,8}$	$SMYM = 178$	$STYM = \sum_i M_{i,17}$	$STYM = 182$
$SMYH = \sum_i M_{i,9}$	$SMYH = 216$	$STYH = \sum_i M_{i,18}$	$STYH = 214$

Analysis step to simplify calculations.

$S_1 = SMBL$	$S_5 = SMGM$	$S_{10} = STBL$	$S_{14} = STGM$
$S_2 = SMBM$	$S_6 = SMGH$	$S_{11} = STBM$	$S_{15} = STGH$
$S_3 = SMBH$	$S_7 = SMYL$	$S_{12} = STBH$	$S_{16} = STYL$
$S_4 = SMGL$	$S_8 = SMYM$	$S_{13} = STGL$	$S_{17} = STYM$
$S_9 = SMYH$		$S_{18} = STYH$	

Calculation of the test statistics.

Sum of the squares for the matrix elements. This term is the same for both management and technical ratings. The term $\text{cols}(M)/2$ is used because the file read in contains two sets of data; management and technical rankings.

$$A2 = \frac{\text{rows}(M) \cdot \frac{\text{cols}(M)}{2} \cdot \left(\frac{\text{cols}(M)}{2} + 1 \right) \cdot \left(2 \cdot \frac{\text{cols}(M)}{2} + 1 \right)}{6}$$

$$A2 = 6.84 \cdot 10^3$$

Square of the column sums added together divided by the number of cases. B2M is for the management case. B2T is for the technical case.

$$K = 1 \dots 9$$

$$L = 10 \dots 18$$

$$B2M = \frac{1}{\text{rows}(M)} \cdot \left[\sum_K (S_K)^2 \right]$$

$$B2T = \frac{1}{\text{rows}(M)} \cdot \left[\sum_L (S_L)^2 \right]$$

$$B2M = 6.647 \cdot 10^3$$

$$B2T = 6.652 \cdot 10^3$$

Calculation of the F-statistic for the null hypothesis. (Null hypothesis is that there is no difference among the different color-risk ratings) The confidence level required is 95%. T2M is the F-statistic for management color risk rating and T2T is the F-statistic for technical color-risk rating.

$$T2M = \frac{(\text{rows}(M) - 1) \cdot \left[B2M - \frac{\text{rows}(M) \cdot \frac{\text{cols}(M)}{2} \cdot \left(\frac{\text{cols}(M)}{2} + 1 \right)^2}{4} \right]}{A2 - B2M}$$

$$T2M = 148.977$$

$$T2T = \frac{(\text{rows}(M) - 1) \cdot \left[B2T - \frac{\text{rows}(M) \cdot \frac{\text{cols}(M)}{2} \cdot \left(\frac{\text{cols}(M)}{2} + 1 \right)^2}{4} \right]}{A2 - B2T}$$

$$T2T = 153.17$$

Calculation of a 95% confidence level statistic.

$$k1 = \frac{\text{cols}(M) - 2}{2}$$

$$k1 = 8$$

$$k2 = k1 \cdot (\text{rows}(M) - 1)$$

$$k2 = 184$$

Using Statistix 4.0 and the values of k1 and k2 above for the degrees of freedom, the F-statistic value is 1.95. Since T2M and T2T are greater than the F-statistic for a 95% confidence interval, the null hypothesis is rejected. The comparison statistic is calculated to identify significant differences in rankings.

Comparison statistic. LevelM is the comparison statistic for the management color-risk rankings and LevelT is for the technical color-risk rankings.

$$\text{LevelM} = 1.95 \cdot \left[\frac{2 \cdot \text{rows}(M) \cdot (A2 - B2M)}{(\text{rows}(M) - 1) \cdot \left(\frac{\text{cols}(M)}{2} - 1 \right)} \right]^{\frac{1}{2}}$$

$$\text{LevelM} = 13.822$$

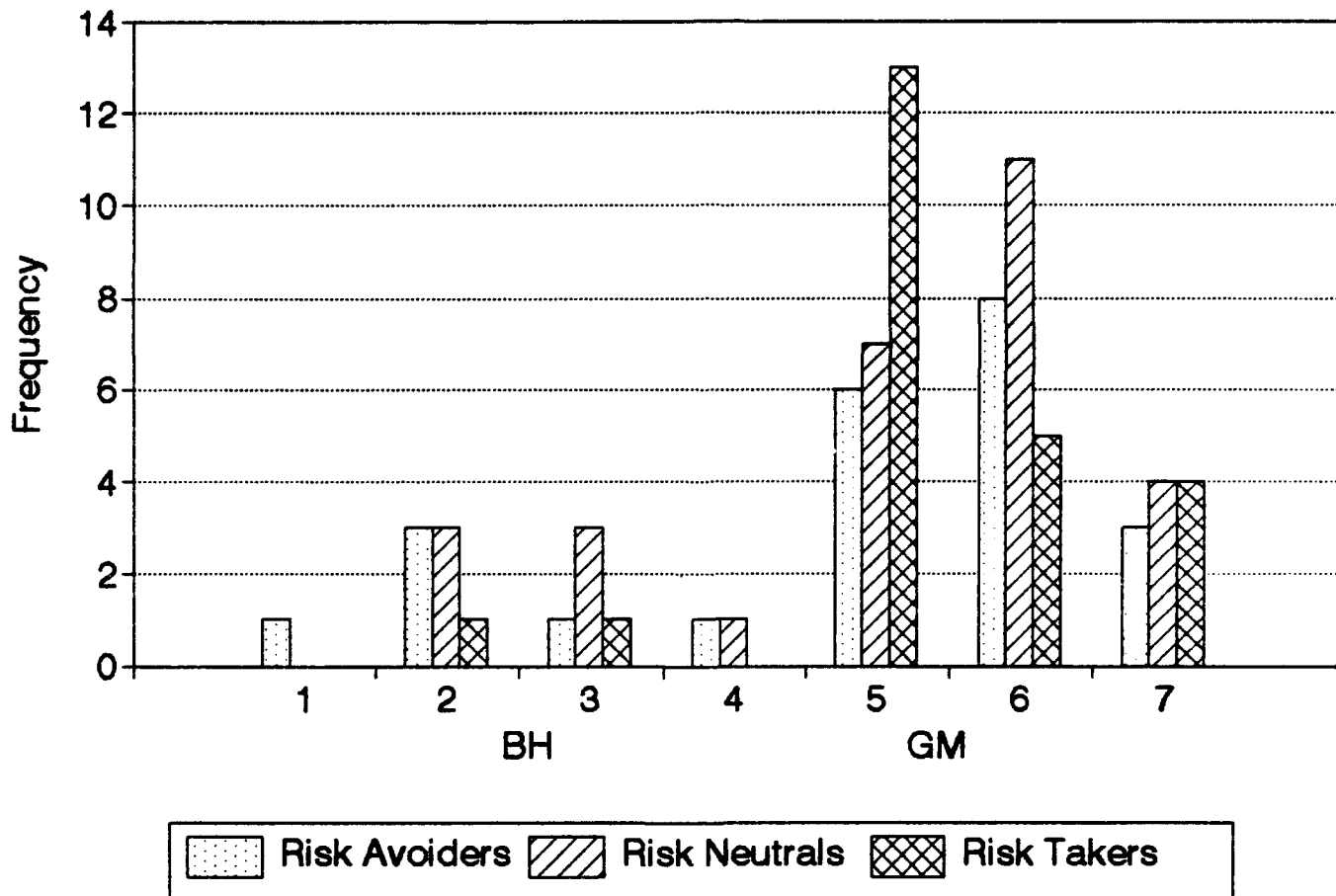
$$\text{LevelT} = 1.95 \cdot \left[\frac{2 \cdot \text{rows}(M) \cdot (A2 - B2T)}{(\text{rows}(M) - 1) \cdot \left(\frac{\text{cols}(M)}{2} - 1 \right)} \right]^{\frac{1}{2}}$$

$$\text{LevelT} = 13.656$$

Appendix C: Response Distributions by Risk Types

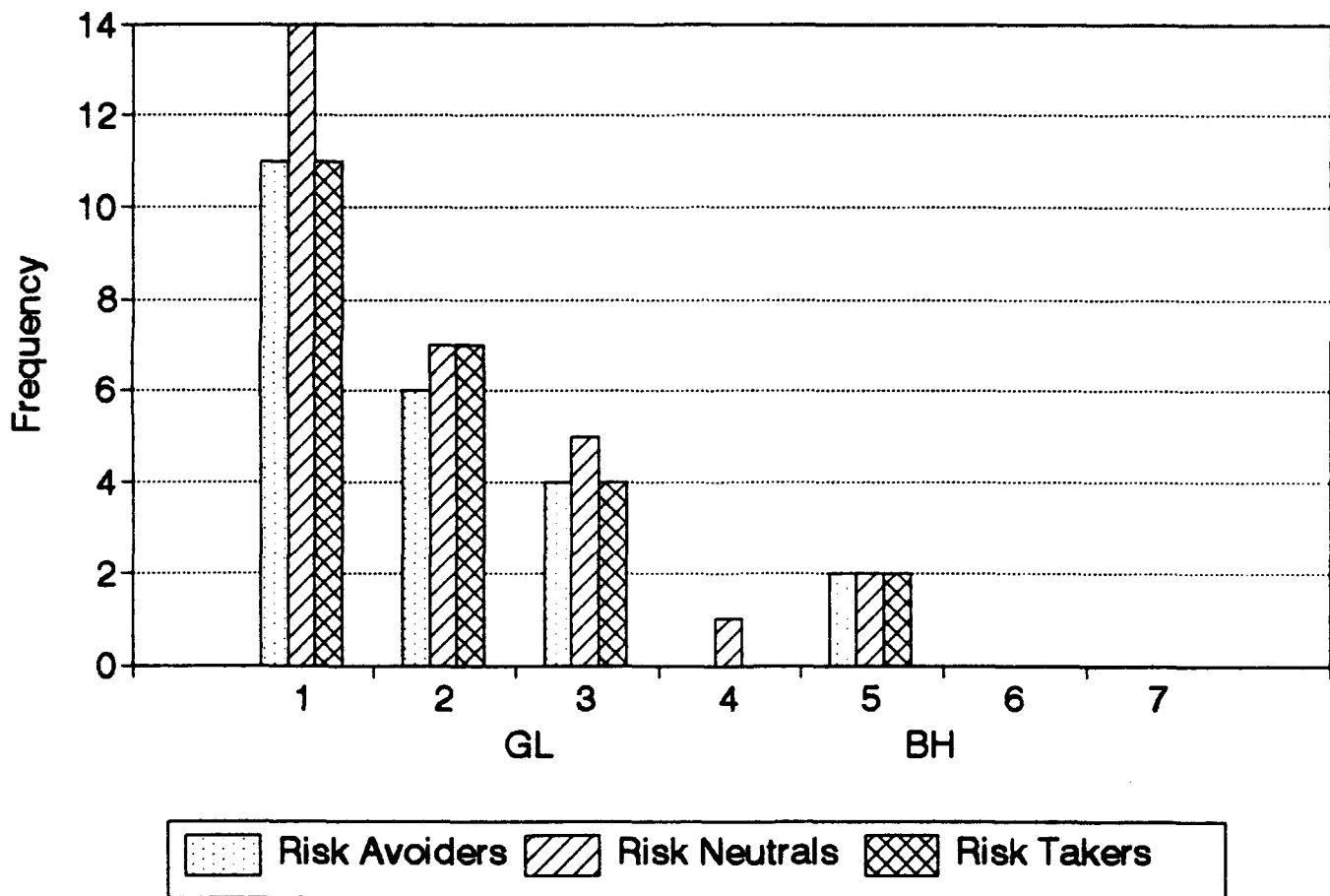
Response Distribution by Risk Types

Question A (Blue High-Green Moderate)



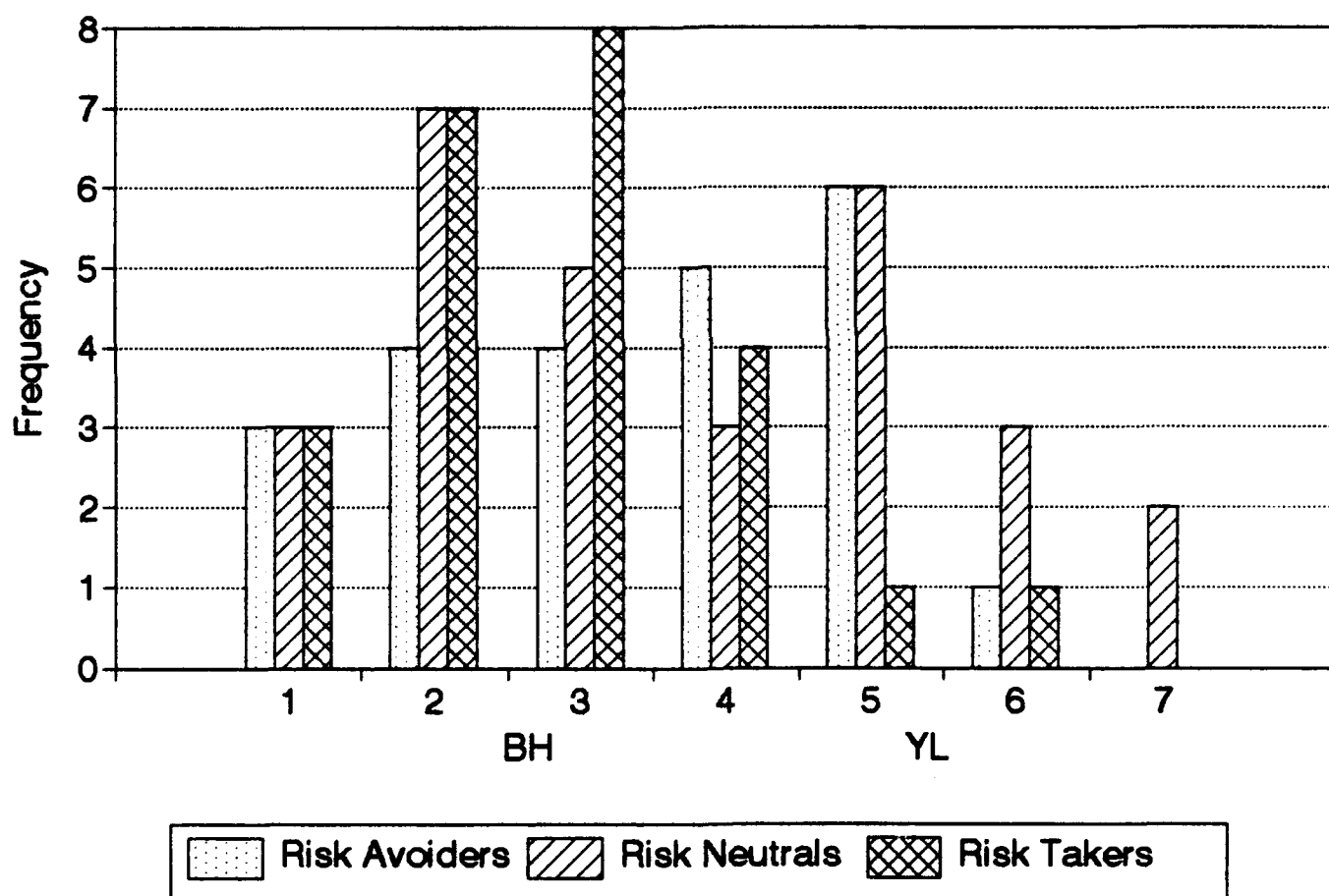
Response Distribution by Risk Types

Question B (Green Low-Blue High)



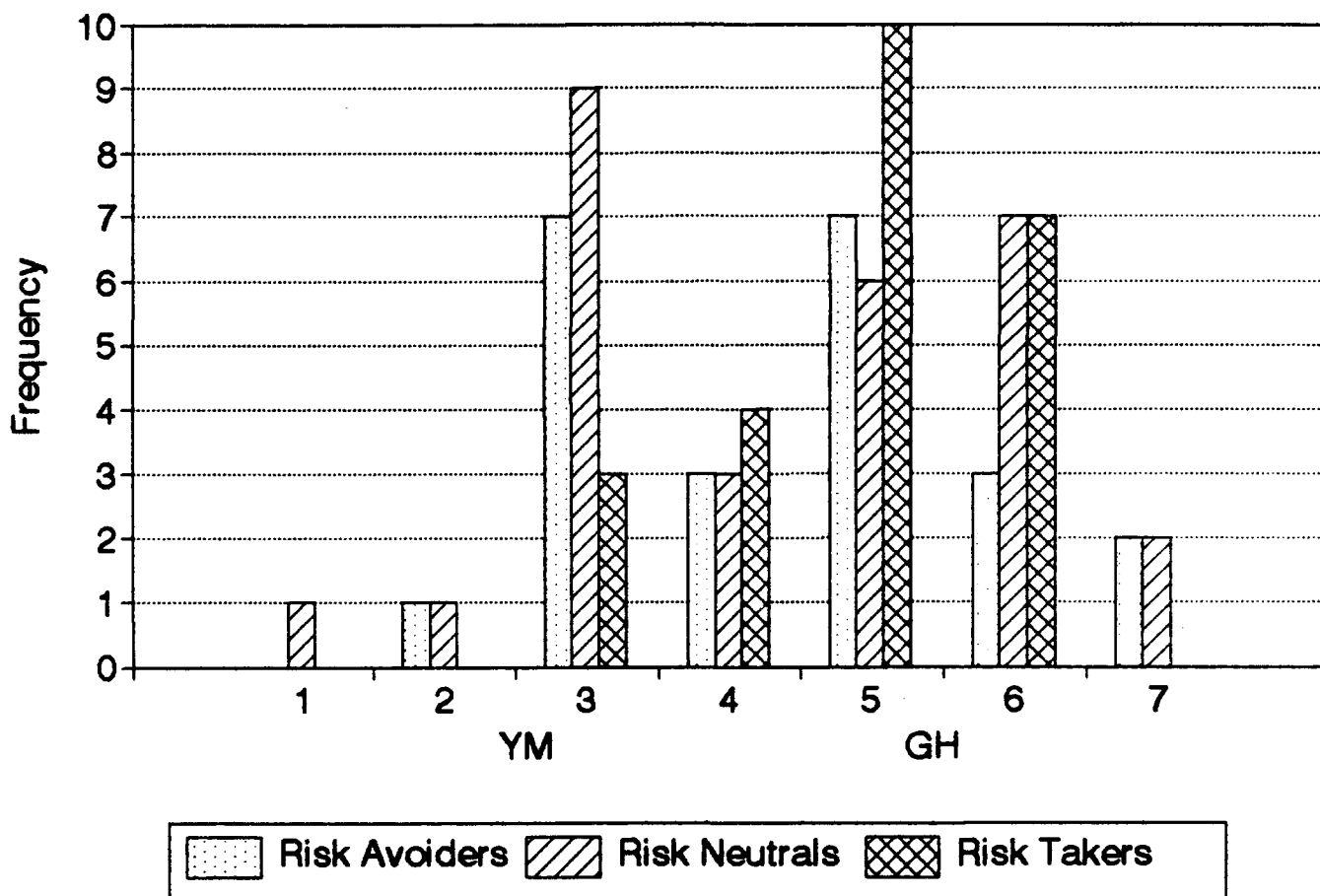
Response Distribution by Risk Types

Question C (Blue High-Yellow Low)



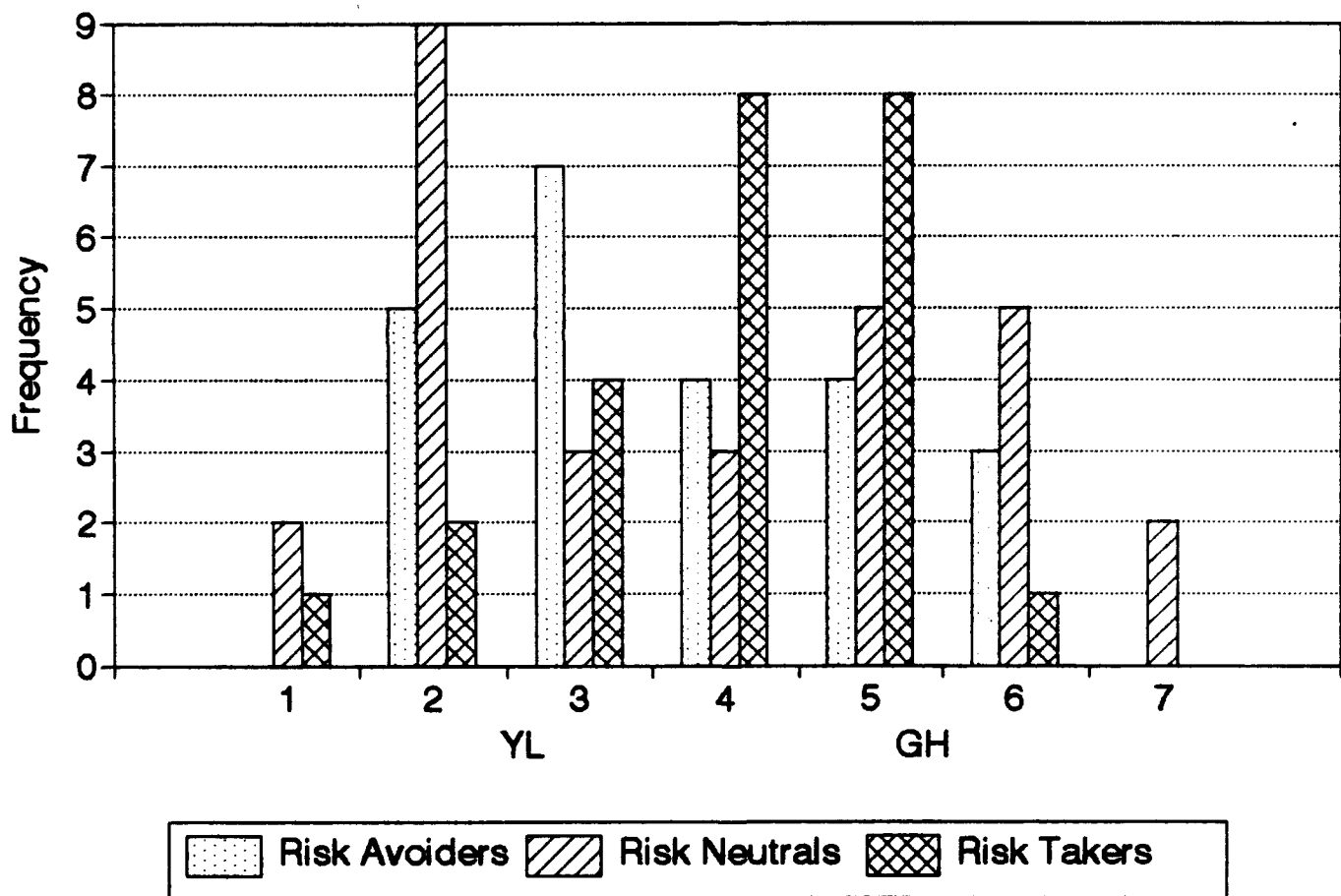
Response Distribution by Risk Types

Question E (Yellow Moderate-Green High)



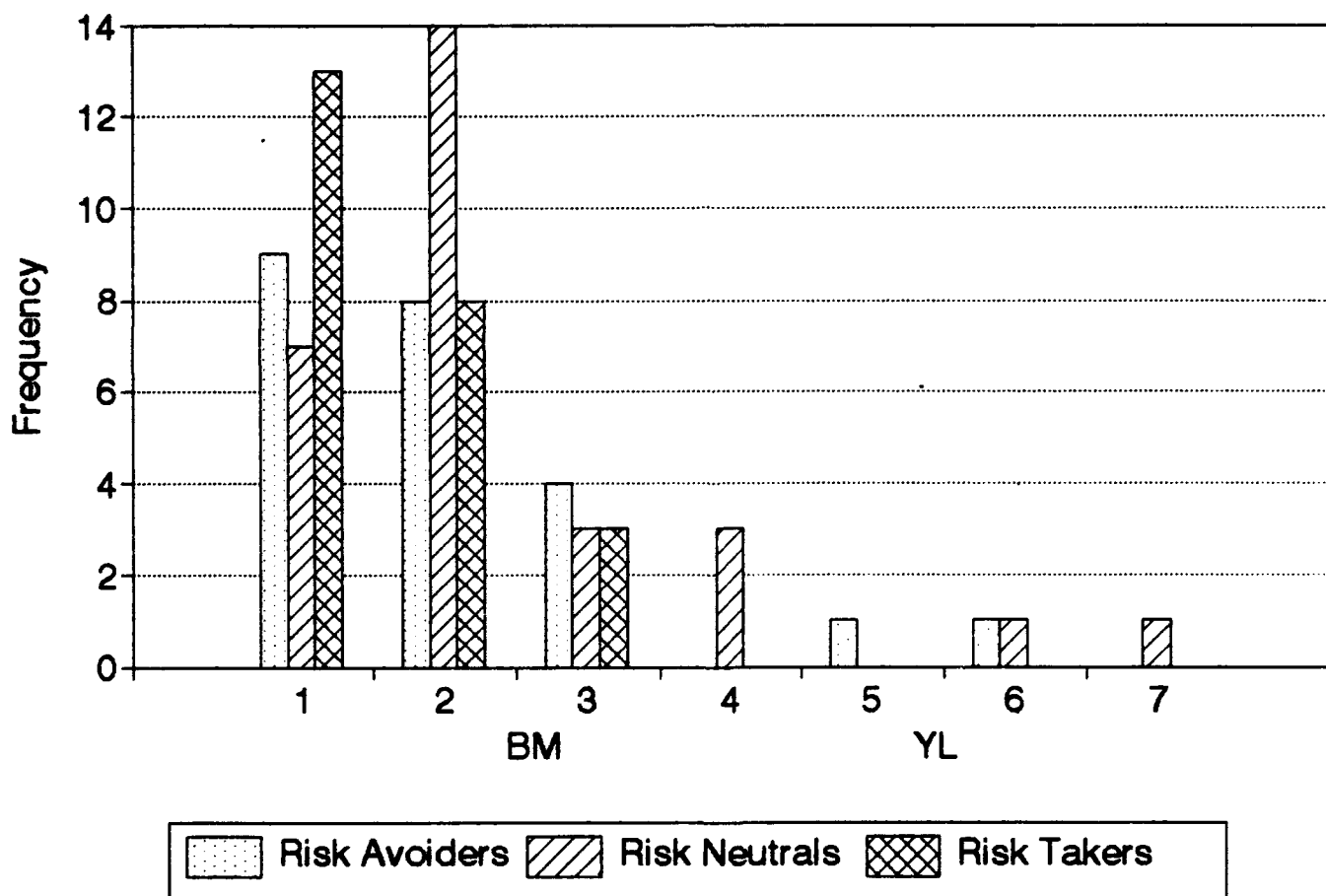
Response Distribution by Risk Types

Question F (Yellow Low-Green High)



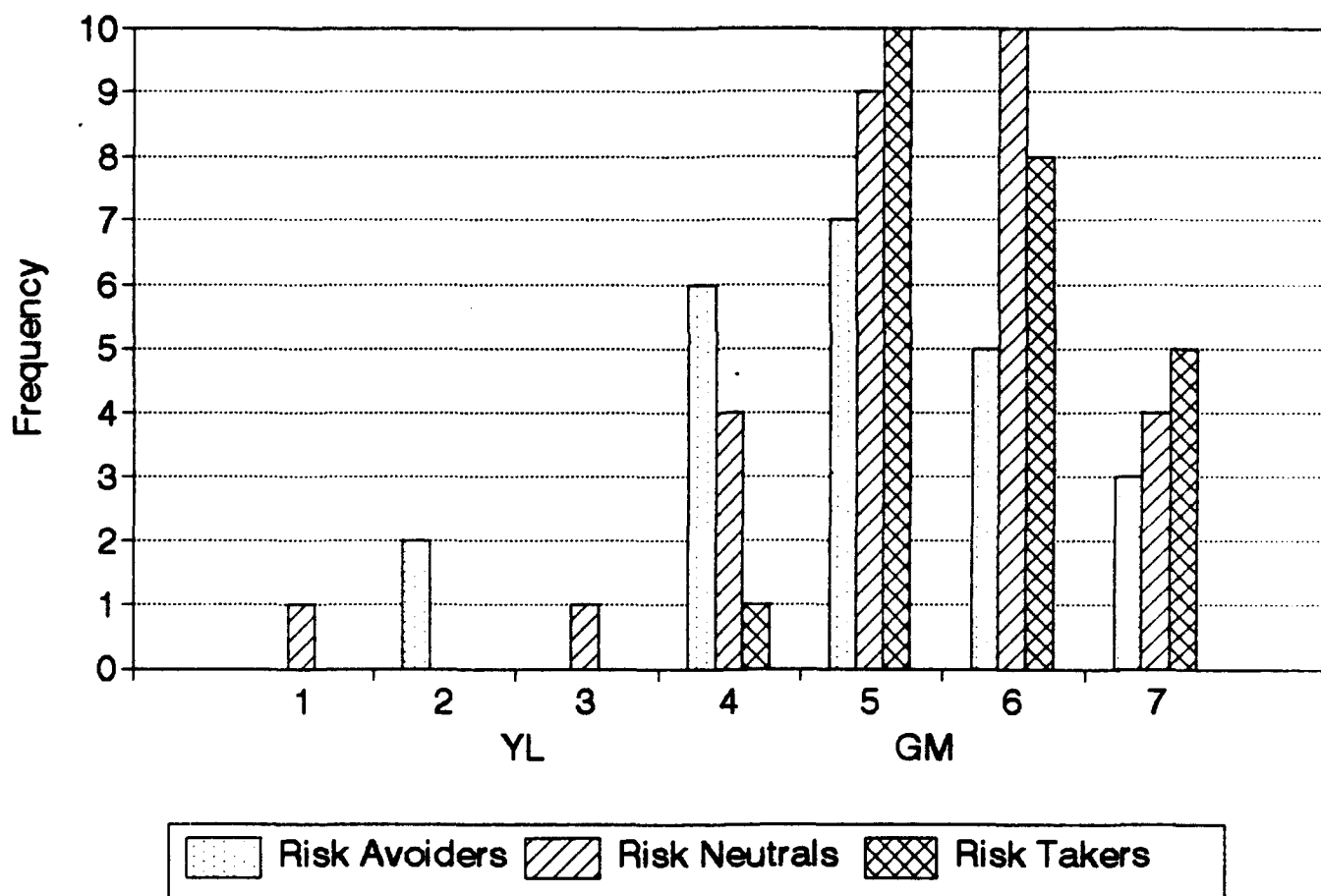
Response Distribution by Risk Types

Question G (Blue Moderate-Yellow Low)



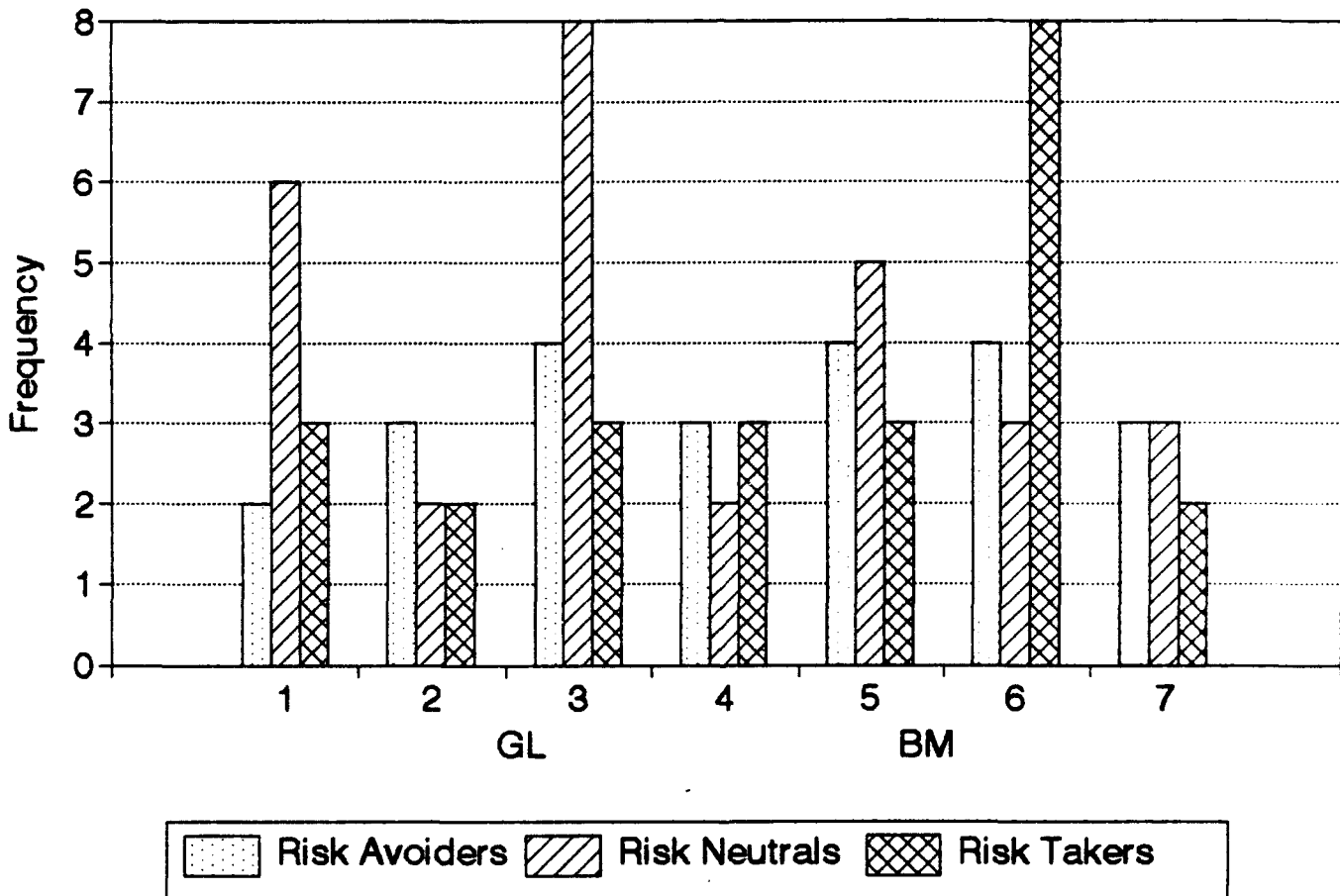
Response Distribution by Risk Types

Question H (Yellow Low-Green Moderate)



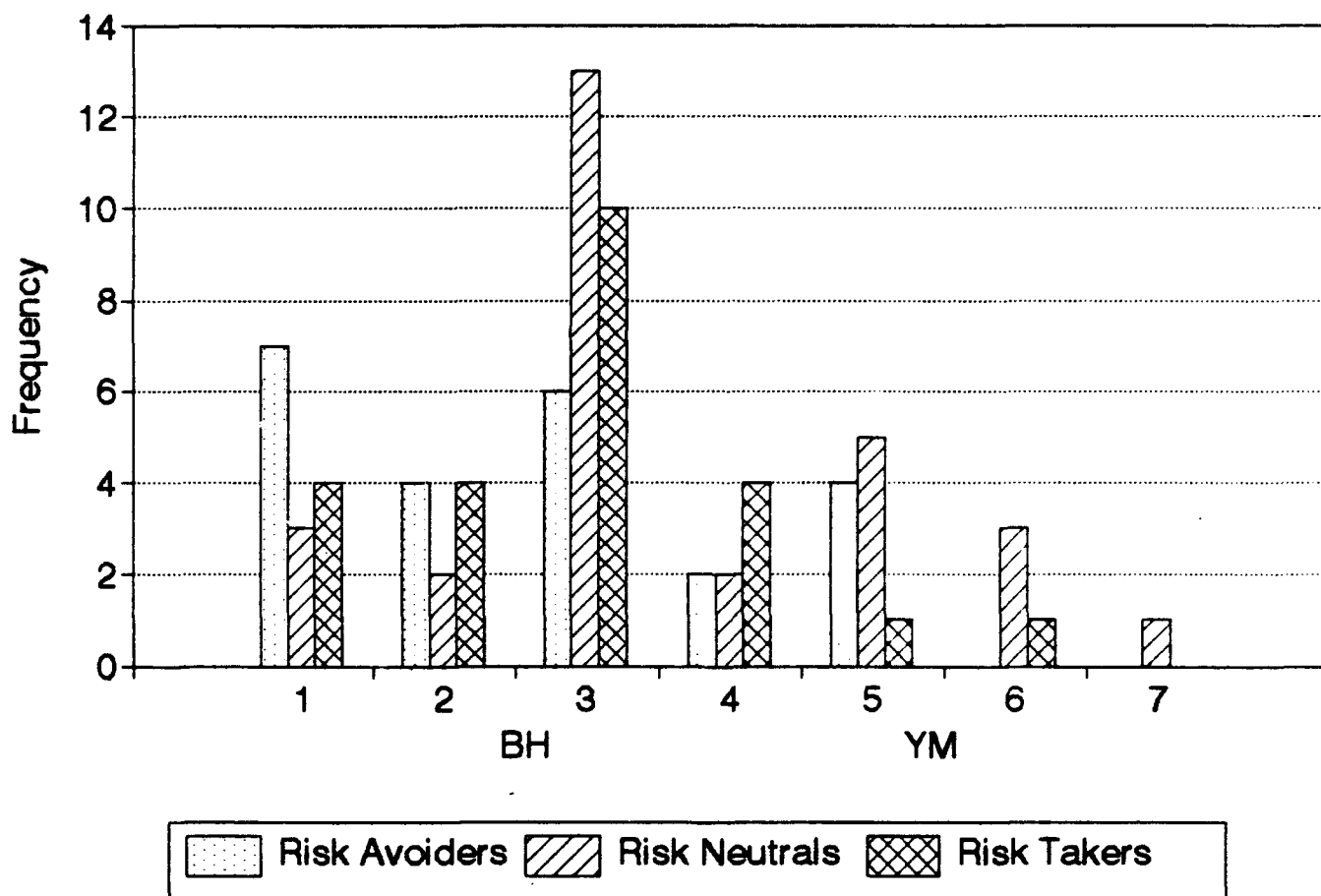
Response Distribution by Risk Types

Question J (Green Low-Blue Moderate)



Response Distribution by Risk Types

Question K (Blue High-Yellow Moderate)



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Vita

Capt Richard G. Pierce, Jr. was born on June 28th, 1965 in Albany, NY. He graduated from Colonie Central High School in 1983. Following graduation he attended Rensselaer Polytechnic Institute in Troy, NY. Capt Pierce graduated from Rensselaer in 1987 with a B.S. in Electrical Engineering. Upon graduation, he received a commission in the USAF through the ROTC program. Capt Pierce was assigned, in May 1988, as an Integrated Logistics Support Manager in the Defense Meteorological Satellite System Program Office, Los Angeles AFB, CA. There he was responsible for developing, guiding, managing and providing direction on supportability in contracts, specifications and program reviews. Capt Pierce performed these functions until entering the Air Force Institute of Technology in May 1992.

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Vita

Lt. Jeffrey E. Wainwright was born on September 5th, 1962 in Amsterdam, NY. He graduated from Scotia-Glenville High School in 1980. Following graduation he attended the State University of New York at Plattsburgh, graduating in 1984 with a B.A. in Geography. After graduation, he entered the U.S. Navy's Aviation Officer Candidate School in Pensacola, FL. He was commissioned as an Ensign in October 1984. Lt. Wainwright began Primary Flight Training at NAS Whiting Field. In April 1985, he was selected for Jet Flight Training and reported to NAS Chase Field. He earned his "wings of gold" in May 1986. He then reported to the VAQ-129 Vikings, as a Fleet Replacement Pilot, located at NAS Whidbey Island, for EA-6B Prowler training. After becoming qualified in the Prowler, he was assigned to the VAQ-134 Garudas. While assigned to the Garudas from April 1987 to August 1990, he made three extended Western Pacific-Indian Ocean deployments on the aircraft carrier U.S.S. Carl Vinson. He next reported back to VAQ-129 as an EA-6B flight instructor. He served in this position until reporting to AFIT in May 1992. He has accumulated over 1700 flight hours (over 1500 in the EA-6B) and 350 carrier arrested landings.

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<small>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.</small>				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE September 1993	3. REPORT TYPE AND DATES COVERED Master's Thesis		
4. TITLE AND SUBTITLE AN ANALYSIS OF THE PERFORMANCE-RISK TRADE-OFF IN SOURCE SELECTION DECISION MAKING		5. FUNDING NUMBERS		
6. AUTHOR(S) Jeffrey E. Wainwright, Lt, USN Richard G. Pierce, Jr., Capt, USAF				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Institute of Technology, WPAFB OH 45433-6583		8. PERFORMING ORGANIZATION REPORT NUMBER AFIT/GSM/LAS/93S-18		
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Request For Proposal and Source Selection Support Program Office, WPAFB OH 45433-6583		10. SPONSORING / MONITORING AGENCY REPORT NUMBER		
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited		12b. DISTRIBUTION CODE		
13. ABSTRACT (Maximum 200 words) <p>Each year the Air Force awards weapon system contracts worth billions of dollars using the source selection process. In the source selection, performance and risk assessments are evaluated to determine the best proposal; the proposal that gives the best overall value. The purpose of this research was to investigate the performance/risk trade-off in the source selection decision making process. The study also examined the effect individual risk propensities and the nature of item being evaluated have on the performance/risk trade-off decisions. Air Force acquisition personnel stationed at Aeronautical Systems Center, Wright-Patterson AFB, OH, who had participated in a source selection were surveyed. The survey required respondents to rank various color-risk combinations used in a source selection from most to least preferred. Respondents also indicated their degree of preference between color-risk rating pairs. Comparisons were made for two item summary levels: technical capability and management. A definite rank order exists among color-risk ratings. The rank is as follows: Blue-Low, Green-Low/Blue-Moderate (tied), Green-Moderate, Blue-High, Yellow-Low, Green-High, Yellow-Moderate, and Yellow-High. Risk propensity and item summary level do not significantly influence the rank order.</p>				
14. SUBJECT TERMS Risk, Acquisition, Air Force Procurement, Decision Making Source Selection, Contract Award		15. NUMBER OF PAGES 115		
		16. PRICE CODE		
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL	

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